4133/34/47/49/63

Instructions and Applications

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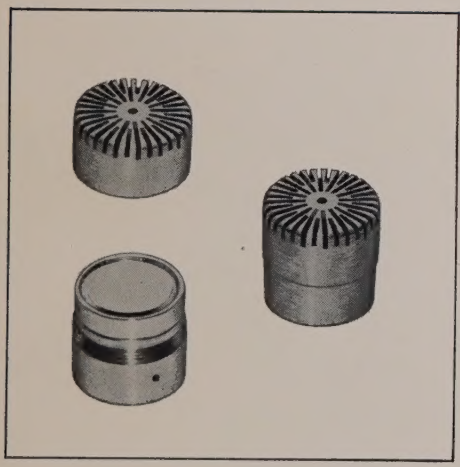

Half-Inch Condenser Microphone Types 4133, 4134, 4147, 4149, 4163

High stability precision condenser microphones for sound measurements. Nominal sensitivity is 12.5 mV per pascal with 200 Volts polarization. The 4147 is particularly intended for use with a Microphone Carrier System, with which its lower frequency limit is 0.01 Hz. The quartz covered membrane and back plate in the 4149 makes it particularly suitable for use in permanent outdoor installations.

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HALF-INCH CONDENSER MICROPHONES

TYPES 4133, 4134, 4147, 4149, and 4163

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1. INTRODUCTION

1.1. GENERAL

The condenser microphone's operating characteristics of high stability, flat linear response, and reasonably high sensitivity, combined with its minimal effect on the sound field in which it is placed, make it for most purposes the most suitable transducer available for measuring sound pressures.

The half-inch microphone cartridges are designed for precision sound pressure measurements. Their range of application covers the frequency range 0.01 Hz to 40 kHz in open circuit frequency response and up to 160 dB sound pressure level. The lower limit of the dynamic range is determined by the noise level of the preamplifier employed. Preamplifiers particularly recommended for use with the half-inch microphones are the B & K Types 2619 and 2615. The 2619 is a FET preamplifier giving an effective lower limiting frequency of 2 to 5 Hz (−3 dB) while the 2615 is a vacuum tube preamplifier which gives the half-inch microphones an effective lower limit of approx. 12 Hz (−3 dB). For measurements at lower frequencies, the Microphone Carrier System Type 2631 extends the useful limit of the microphone down to the limit of its pressure equalization system. For the Type 4147 (with adaptor UA 0271), this limit is below 0.01 Hz.

The upper limit of the linear frequency response depends on the individual microphone selected. The 4133, 4149 and 4163 are designed for linearity in their free field responses, the open circuit free field response being linear up to 40 kHz (± 2 dB). The 4134 is designed for linear pressure response up to 20 kHz (± 2 dB). The 4147 is also a linear pressure response microphone, but it has also been designed to respond linearly in the infrasonic frequency range (down to 0.01 Hz ± 1 dB), its upper limit of linearity is 16 kHz (± 1 dB).

The half-inch microphones fulfil the American Standard ANSI S1.12−1967 for type M Laboratory Standard Microphones. Their most outstanding feature is excellent long-term stability under a great range of

environmental conditions and especially their insensitivity to temperature variations. They are therefore suited for field measurements, though their accuracy of calibration matches laboratory standard requirements. An extensive series of accessories provides a great measuring versatility.

1.2. PRINCIPLE OF THE CONDENSER MICROPHONE

The condenser microphone is a transducer which converts energy from mechanical to electrical form and vice-versa. The conversion is effected by mechanically inducing changes in electrical capacitance between two conducting plates separated by an insulator, and detecting the capacitance changes electrically. There are two major principles which can be used to detect these capacitance changes. The conventional method is to load the microphone with the very high input resistance of a preamplifier and measure the voltage appearing across that resistance. The alternative is to use the capacitance variations to frequency modulate a carrier frequency, detection being by a conventional demodulator. The former method is discussed below. For a review of the carrier system principle, reference should be made to the instruction manual for the Microphone Carrier System Type 2631.

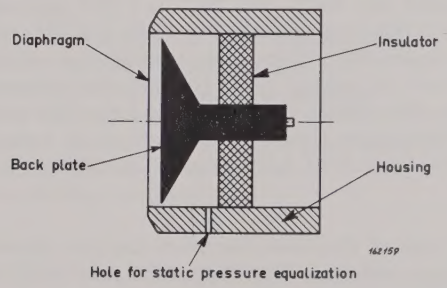


Fig. 1.1. Schematic Diagram of a Condenser Microphone

A condenser microphone consists essentially of a thin metallic diaphragm mounted in close proximity to a rigid back plate, each being electrically insulated from the other and forming the electrodes of a capacitor (Fig. 1.1). A stabilized DC polarization voltage maintains a constant charge between the electrodes, provided the time constant of the charging circuit is much longer than the period of the sound pressure variations. When sound

pressure waves are incident on the diaphragm, the capacitance changes and a voltage is produced. By careful design, the output voltage is made proportional to the sound pressure level through extended frequency and dynamic ranges.

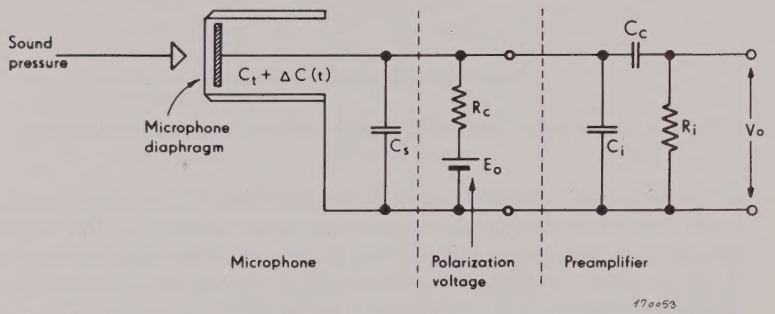


Fig.1.2. Simplified Circuit Diagram of Condenser Microphone and Preamplifier

A simplified circuit diagram of a condenser microphone and preamplifier is shown in Fig.1.2 and its equivalent circuit in Fig.1.3. The output voltage is given by:

$$V_o = \frac{\Delta C(t)}{C} \cdot E_o \cdot \frac{j\omega RC}{1 + j\omega RC}$$

where E_o = polarization voltage
C_t = capacitance of microphone cartridge
$C(t)$ = variation in capacitance due to sound pressure
C_s = stray capacitance
C_c = coupling capacitance
C_i = input capacitance of preamplifier
C = $C_t + C_s + C_i$
R_c = charging resistance
R_i = input resistance of preamplifier

$$R = \frac{R_i R_c}{R_i + R_c}$$

$C_c \gg C$ and is therefore neglected in the equivalent circuit

It is seen that the sensitivity is proportional to the polarization voltage but inversely proportional to the total capacitance C. Any capacitance

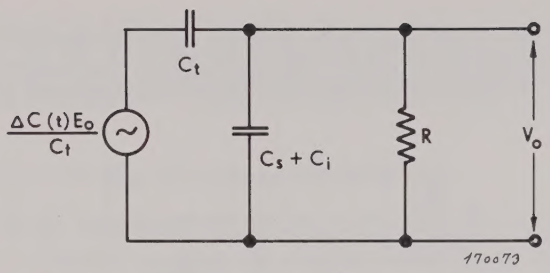


Fig. 1.3. Equivalent Circuit of Condenser Microphone and Preamplifier

additional to the transducer capacitance, such as that of the preamplifier, would load the transducer and decrease the output voltage V_o. This means that the total capacitance in the circuit should not exceed the capacitance of the transducer by more than is absolutely necessary. Hence the need for integral construction of the cartridge and preamplifier.

1.3. FREE FIELD AND PRESSURE RESPONSE

The sensitivity of a transducer is normally expressed as the ratio of its electrical output to its acoustic input and is, in general, a function of frequency. When the sound pressure is applied uniformly over the surface of the diaphragm, the ratio of the RMS output voltage V_o, to the RMS sound pressure, p_1, is called the pressure response, M_p, of a microphone at a given single frequency and written as

$$M_p = \frac{V_o}{p_1}$$

The relative pressure response level, R_p in dB, of a microphone is often defined with respect to a reference sensitivity of 1 volt per pascal.*

The Free Field Response level, M_f, at a given frequency is defined as the ratio of RMS output voltage, V_o, to RMS sound pressure, p_o, existing before the microphone is placed in the field so

$$M_f = \frac{V_o}{p_o}$$

---

* 1 pascal = 1 N/m^2 = 10 μbar.

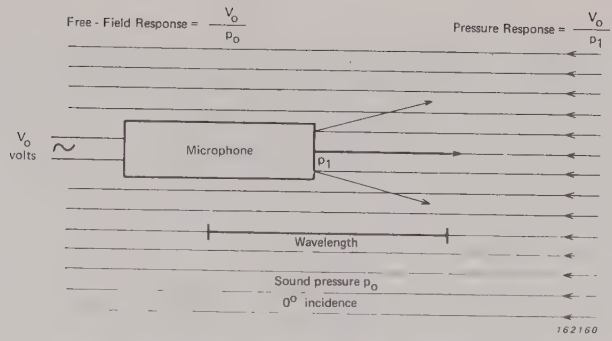


Fig.1.4. Definition of Free Field and Pressure Response

The definition of Free Field and Pressure Response are illustrated in Fig.1.4. The two definitions are identical for a microphone having negligible dimensions compared to the sound wavelength. If the wavelength becomes comparable to microphone dimensions, reflection and refraction of sound waves due to the microphone body produce a local change in the sound pressure. This causes an increase in pressure on the diaphragm which results in an increased output voltage. These effects are variable with the angle of incidence of the sound.

The free field behaviour of a microphone is thus described by means of a set of free field correction curves for various incidences, which should be added to the pressure frequency response curve of the microphone in each particular case.

Compensation for the normal incidence free field corrections can be achieved by damping the diaphragm resonance. This can be done to microphones intended for free field work, in order to give a flat frequency response at frequencies above the resonance frequency.

The free field response of a microphone is of interest when the transducer is operated in an open space, many wavelengths removed from a sound source or reflecting boundaries. The pressure response is important in closed cavities, couplers, artificial ears, etc.

1.4. DIFFUSE FIELD (RANDOM INCIDENCE) RESPONSE

The Diffuse Field (Random Incidence) response of a microphone for a given frequency is the RMS value of the free field sensitivity for all angles of

incidence of the sound wave. It corresponds to the diffuse field sensitivity of the microphone. The diffuse field is a sound field in which the sound energy density is uniform and the mean acoustic power per unit area is the same in all directions. The International Electrotechnical Commission — publication No. 123 § 8.2 — has given a practical rule for the calculation of the random incidence sensitivity from the free field sensitivities at definite angles, with coefficients proportional to the relative solid angles. If S_o, S_{30}, S_{60}, ---S_{180} are the sensitivities of the microphone at angles of incidence of 0^o, 30^o, 60^o, ---180^o, the random incidence (diffuse field) response S is given by the formula:

$$S^2 = 0.018\,(S_o{}^2 + S_{180}{}^2) + 0.129\,(S_{30}{}^2 + S_{150}{}^2)$$

$$+ 0.224\,(S_{60}{}^2 + S_{120}{}^2) + 0.258\,S_{90}{}^2$$

Figs.2.7 and 2.8 show the random incidence frequency response of the half-inch microphones. These curves should be used when taking measurements in reverberant conditions. The sound field in very reverberant rooms can be considered as a diffuse sound field.

When the spectral distribution of the sound varies with the angle of incidence, correct integration is only possible in the range where the microphone is both linear and omnidirectional. Omnidirectional microphones are also necessary in the case of rapidly moving sound sources (aeroplanes, motorcars, etc).

2. DESCRIPTION

2.1. GENERAL

A complete microphone consists of a microphone cartridge and a preamplifier for impedance conversion, permitting the use of long cables and measuring instruments with a relatively low input impedance. For the half-inch microphone cartridges 4133, 4134, 4149 and 4163 the preamplifier Types 2615 and 2619 are recommended. For the 4147, the Microphone Carrier System 2631 with adaptor UA 0271 is recommended. Dimensioned sketches of the microphone and preamplifier or carrier system head are shown in Figs.2.1 and 2.2.

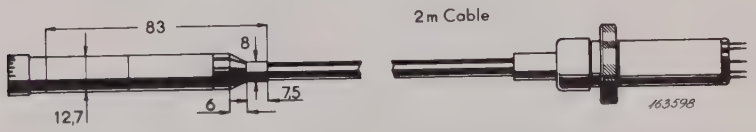


Fig.2.1. Dimensions (in mm) of 4133, 4134, 4149, or 4163 fitted to Cathode Follower

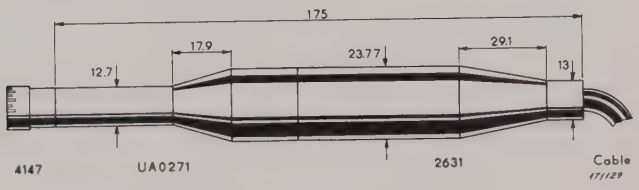


Fig.2.2. Microphone Type 4147 fitted to Microphone Carrier System Type 2631

The purposes of the five half-inch condenser microphones are:

Type 4133 is designed to have a free field characteristic for sound incidence normal to the microphone diaphragm which is linear to the highest possible frequency (40 kHz).

Type 4134 is designed to have a pressure response characteristic (or a diffuse field characteristic – the design considerations are similar) which is linear to the highest possible frequency (20 kHz).

Type 4147 is designed to have a diffuse field response which is linear to the highest possible frequency (16 kHz) while at the same time having a linear response to as low a frequency as possible (0.01 Hz).

Type 4149 is acoustically similar to the 4133. It has in addition an improved humidity and diaphragm corrosion resistance which makes it amply suitable for permanent outdoor installations. The diaphragm and back plate are covered with a thin layer of quartz, see Fig.2.3, which serves the following purposes:

– on the thin diaphragm it reduces the (inherent) porosity which would otherwise allow moisture in high humidity conditions to penetrate, and at the same time it protects the diaphragm against corrosion,

– on the back plate it protects the surface against corrosion which might result from a combination of humidity and subsequent condensation, and the very high electric field between the diaphragm and the back plate (100 kV/cm).

The quartz layer adds only 4% to the mass of the diaphragm which results in a negligible change in the microphone's electroacoustic properties when compared with the 4133.

The pressure equalization hole is led out to the other side of the quartz insulator, see Fig.2.3, where it can be supplied with dry air via a UA 0308 Dehumidifier if the microphone is required to operate in humid conditions.

Type 4163 is acoustically similar to the 4133. It differs only in the design of its pressure equalization hole which, like the 4149, is led out to the other side of the quartz insulator where it can be supplied with dry air via a UA 0308 Dehumidifier under humid conditions.

Fig.2.4 shows some of the main internal components of the 4133 and 4134 cartridges. Except in the position of the pressure equalization hole, the details apply equally to the 4149 and 4163. Dimensional details are

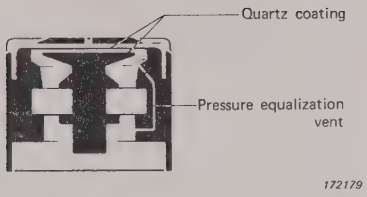


Fig.2.3. Cross sectional view of microphone 4149

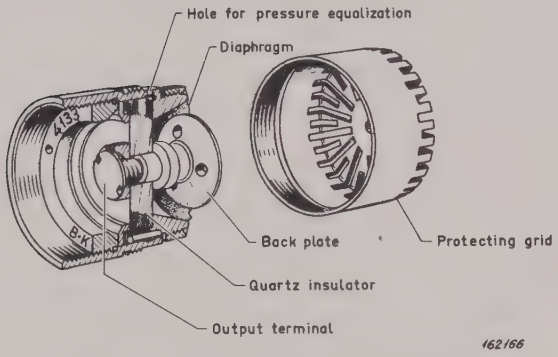


Fig.2.4. Exploded view of 4133 cartridge

shown in Fig.2.5. The 4133, 4149 and 4163 differ from the 4134 in the back plate which in the free field microphones provides greater damping of the diaphragm. This ensures the correct pressure response fall-off with increasing frequency such that the free-field response remains linear. All diaphragms are constructed from pure nickel, approx. 5 μm thick (the quartz layer on the 4149 diaphragm and back plate is 0.7 μm thick) and are mounted at a distance of 20 μm away from the back plate.

The Type 4147 is also constructed according to the same principle as that shown in Fig.2.4 except that the hole for static pressure equalization is of a different design in order to obtain the special low frequency response required. It is also led out to the other side of the quartz insulator. Also, the internal volume of the cartridge is increased in order to reduce the cut-off frequency. Its detail dimensions are shown in Fig.2.6. The diaphragm is of pure nickel, 5 μm in thickness. It is mounted at a distance of 20 μm from the back plate.

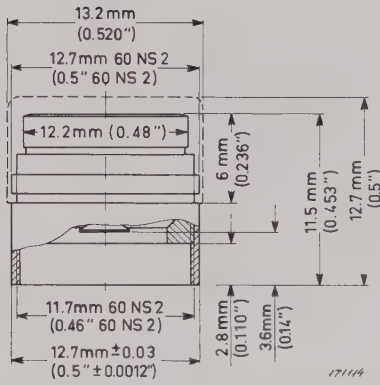


Fig.2.5. Dimensions of the half-inch microphone cartridges 4133, 4134, 4149 and 4163

For each microphone type, the case is of a high nickel alloy (K-Monel).

The insulator is of silicone treated quartz. The output terminal is gold plated to ensure noiseless contact. The cartridges are artificially aged during manufacture in order to guarantee stability in use. All materials, design

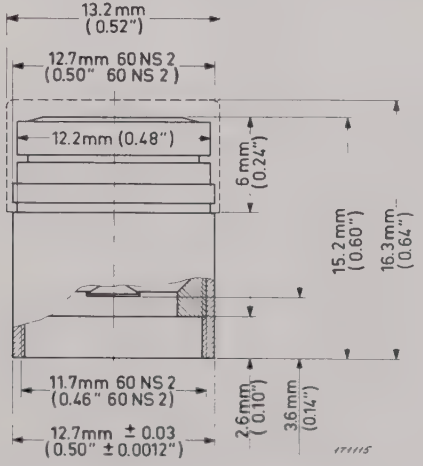


Fig.2.6. Dimensions of the half-inch microphone cartridge 4147

details and construction methods have been chosen with the object of obtaining the best possible long-term stability and freedom from environmental conditions.

Individual calibration charts are provided with every microphone, showing details of its calibration at the factory. The 4133, 4134, 4149 and 4163 are calibrated with 200 Volts polarization in the frequency range above 20 Hz. The 4147 is calibrated with 28 Volts polarization in the same range, as the frequency response at this low polarization voltage is the same as its response with the Microphone Carrier System. For practical reasons, the calibration of low frequency response of the 4147 is performed by a different method. This is described fully in section 3.6.3. Leakage resistance across the capacitor plates is individually verified at the factory to be above $10^{16}\ \Omega$ at 52% relative humidity. Examples of typical calibration charts are shown in Fig.2.7.

Cleansing of the Microphone Diaphragm

CAUTION. On no account should the diaphragm come into contact with fingers or other objects. The protecting grid should only be removed when necessary. Should the diaphragm become contaminated by liquids or dust it may be dried off with cotton wool or a very soft paintbrush, using great care, and if necessary a proper solvent. The diaphragm will not normally corrode, but any appreciable added mass will change the response at high frequencies.

The most important characteristics are individually calibrated at the factory. The calibration chart for each cartridge is fastened inside the lid of its case. Typical calibration charts are shown in Fig.2.7. The layout of the calibration charts for Types 4149 and 4163 are similar to that for Type 4133.

2.2. SENSITIVITY

2.2.1. Open Circuit Sensitivity

The comments which follow apply particularly to the microphones when used with a preamplifier. Some modification of these comments is necessary when considering use with the Microphone Carrier System and for these aspects reference should be made to the instruction manual for the Type 2631 Microphone Carrier System.

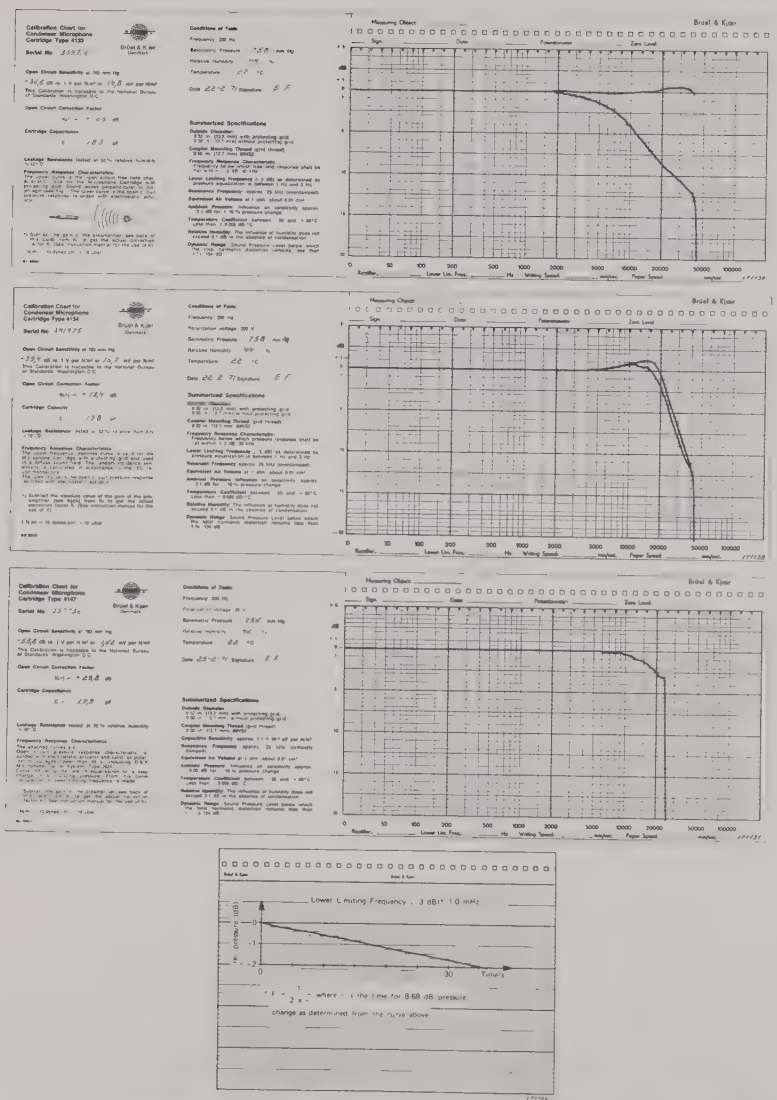

Calibration Chart for Condenser Microphone Cartridge Type 4133
Bruel & Kjær
Measuring Object
Bruel & Kjær
Calibration Chart for Condenser Microphone Cartridge Type 4134
Calibration Chart for Condenser Microphone Cartridge Type 4147
Lower L muting Frequency . 3 dB re 1.0 mHz
Time/s
change as determined from the curve above

Fig.2.7. Individual calibration charts for the microphones (a) Type 4133 (b) Type 4134 (c) and (d) Type 4147

The Open Circuit Sensitivity is the sensitivity of the microphone when the cartridge is not loaded by a preamplifier, stray capacitance etc. This sensitivity is measured for the individual cartridge at 250 Hz with 200 Volts polarization (for 4133, 4134, 4149 and 4163) or 28 Volts polarization (for 4147) and is given on the calibration chart. The nominal open circuit sensitivity of the cartridges is 12.5 mV per pascal* (−38 dB re 1 volt per pascal) with 200 volts polarization and 1.58 mV per pascal (−56 dB re 1 V per pascal) with 28 volts polarization. However, the cartridges are individually calibrated and the actual open circuit sensitivities may lie between ± 2 dB of the nominal values.

The sensitivity of the complete microphone (i.e. microphone cartridge and preamplifier) may be calculated from the following formula:

$$S_1 = S_o \cdot A \cdot \frac{Ct}{Ct + C}$$

where S_1 = sensitivity of the complete microphone
S_o = open circuit sensitivity of the cartridge (given on the calibration chart)
C_t = cartridge capacitance
C = effective input capacitance of the preamplifier
A = voltage gain of the preamplifier.

Example:

If the Type 4133 cartridge is used together with the Type 2615 Cathode Follower, then using nominal values:

S_o = 12.5 mV per pascal
A = 0.91 (−0.8 dB)
C_t = 18 pF
C = 3 pF

So: $S_1 = 12.5 \cdot 0.91 \cdot \frac{18}{18 + 3}$ mV per pascal).

S_1 = 9.75 mV per pascal (−40.2 dB re 1 volt per pascal).

The 2615 Cathode Follower therefore decreases the nominal sensitivity of the microphone by about 2 dB.

---

* 1 pascal = 1 N/m^2 = 10 μbar.

2.2.2. Correction Factor

Some B & K instruments are calibrated for a standard microphone sensitivity of 50 mV per pascal, i.e. −26 dB relative to 1 V per pascal. Since the microphone, or the microphone plus preamplifier, may differ from this sensitivity, a correction factor must be added to the meter reading of these instruments to get the actual level. Thus, the sound level in dB, measured by an instrument calibrated to a 50 mV standard microphone sensitivity, is equal to the meter reading of the instrument plus the attenuator setting, if any, plus the correction factor K.

K is the correction factor for the combination of microphone cartridge plus preamplifier. K_o, the correction factor of the microphone cartridge alone is given on the calibration chart supplied with the microphone cartridge. The correction factors are related as follows:

$$K = K_o - G$$

where G is the gain of the preamplifier in dB. G includes the effect of transducer capacitance, and it is usually negative.

$$G = g + 20 \log_{10} \frac{C_t}{C + C_t}$$

where C_t is the microphone capacitance (given on the calibration chart), C is the effective input capacitance of the preamplifier, and g is the gain of the preamplifier alone. On the back of the calibration chart supplied with each microphone is a table of the typical gain of various B&K preamplifiers.

Although this method of calculating the overall sensitivity of the microphone and preamplifier gives reasonable accuracy in practice, when the most accurate measurements possible are to be made, it is necessary to know exactly the input capacitance of the individual preamplifier. Even better in practice, however, when seeking optimum accuracy is to use the Pistonphone or Sound Level Calibrator for overall calibration of the system.

Even if the Pistonphone or Sound Level Calibrator is used, however, calculation of sensitivity still provides a useful cross-check. If the difference between the two calibration methods is not great, it is then reasonable to assume that the frequency response of the microphone is also as shown on its calibration chart.

2.3. FREQUENCY RESPONSE

The calibration chart provided with each microphone cartridge (Fig.2.7) gives the individually measured relative open circuit frequency response determined by the electrostatic actuator method. The calibration is valid down to a frequency of 20 Hz, but it may reasonably be assumed that the microphone response is linear down to the approach of the lower limiting frequency as determined by its pressure equalization. However, in order to obtain the true frequency response of the microphone with its preamplifier, the response of the preamplifier must be added to that of the microphone. The response of the preamplifier as loaded at its input by the capacitance of the microphone, may be found in the relevant instruction manual. In most cases the influence of the preamplifier response is negligible, but if measurements using a preamplifier must be performed below 20 Hz, or if the preamplifier is loaded with a long cable, there may be an influence of some significance.

The calibration curve of frequency response is for 200 volts polarization of the 4133, 4134, 4149 and 4163 and with 28 volts polarization of the 4147. The frequency response of the 4147, when used with adaptor UA 0271 and the Microphone Carrier System 2631, is identical to its response with 28 volts polarization and a conventional preamplifier.

The calibration gives the open circuit pressure response of the microphone. To the calibration chart of the 4133 (4149 and 4163) cartridge (Fig.2.7a) is added the correction to give the normal incidence of free field response with the protecting grid fitted. This involves adding the 0^{o} incidence free field correction (Fig.2.8) to the basic pressure response of the microphone. Fig.2.7b shows the pressure response curve of the 4134, to which is added the correction for random incidence, as obtained from Fig.2.8. For the 4147, only the pressure response curves are given (Fig.2.7c).

2.3.1. Low Frequency Limit (–3 dB point)

At frequencies below 20 Hz, the response of the microphone cartridge continues as a straight line until close to the lower frequency limit (–3 dB point). For the 4133, 4134, 4149 and 4163 this frequency is between 1 Hz and 3 Hz, while for the 4147 the –3 dB point is between 1 mHz (0.001 Hz) and 5 mHz. Below the lower frequency limit, the response of the microphone falls by 20 dB per decade.

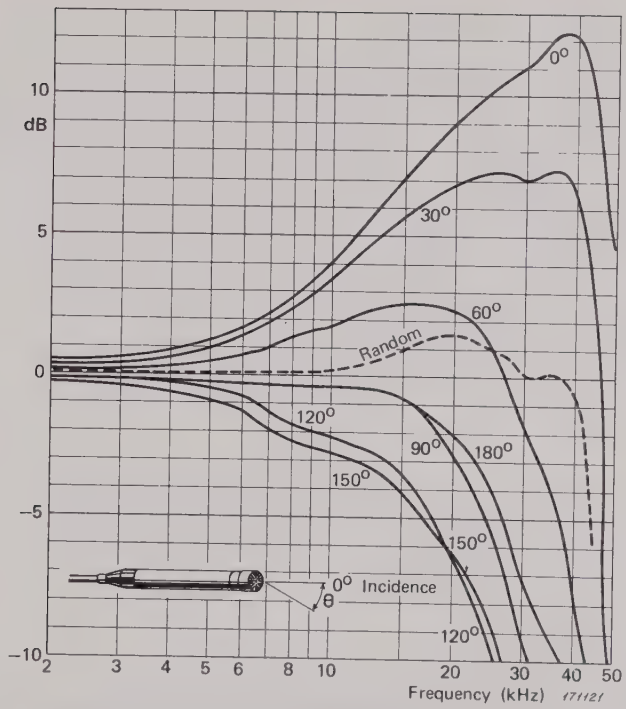


Fig.2.8. Free field and random incidence corrections for the microphone cartridges with protective grid

The lower limiting frequency is determined by the static pressure equalizing system, which ensures that sensitivity of the microphone is not affected by small changes in ambient pressure. The purpose of the very low limit of the 4147 is to give the response required for short duration impulsive sounds. The requirements of the ISO draft standard for sonic boom measurements are fulfilled by the 4147.

For the method used in calibration of the lower limiting frequency, see section 3.6.3.

2.3.2. Free Field Corrections

The pressure increase which is caused by diffraction and reflection of free field sound waves on the microphone becomes appreciable above 2 kHz. The corresponding correction curves, which are valid for the five cartridges are given in Figs.2.8 and 2.9. The frequency response for the various angles of incidence is obtained by adding the free field correction to the pressure response supplied with each cartridge. When mounting a Nose Cone on the microphones, however, the free field corrections are less dependent on the angle of incidence. See section 4.1. The random incidence corrections, S, are calculated according to the formula given in the recommendations of the IEC for Sound Level Meters (IEC 123 § 8.2):

$$S^2 = 0.018\,(S_0^2 + S_{180}^2) + 0.129\,(S_{30}^2 + S_{150}^2) + 0.224\,(S_{60}^2 + S_{120}^2) + 0.258\,S_{90}^2$$

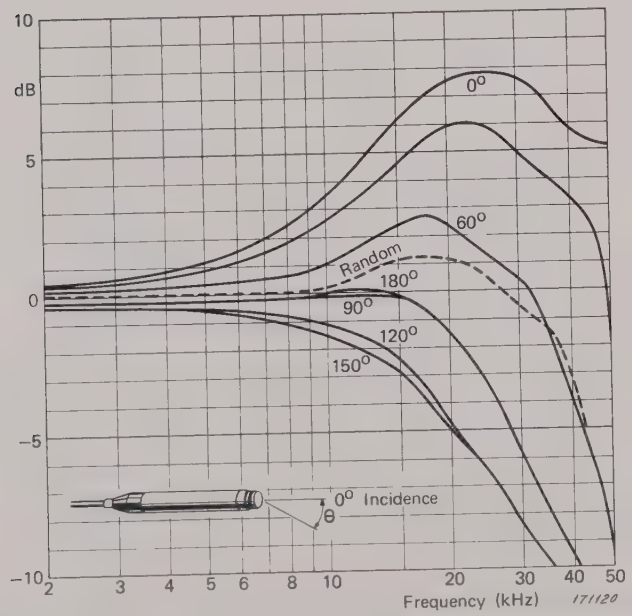


Fig.2.9. Free field and random incidence corrections for the microphone cartridges without protective grid

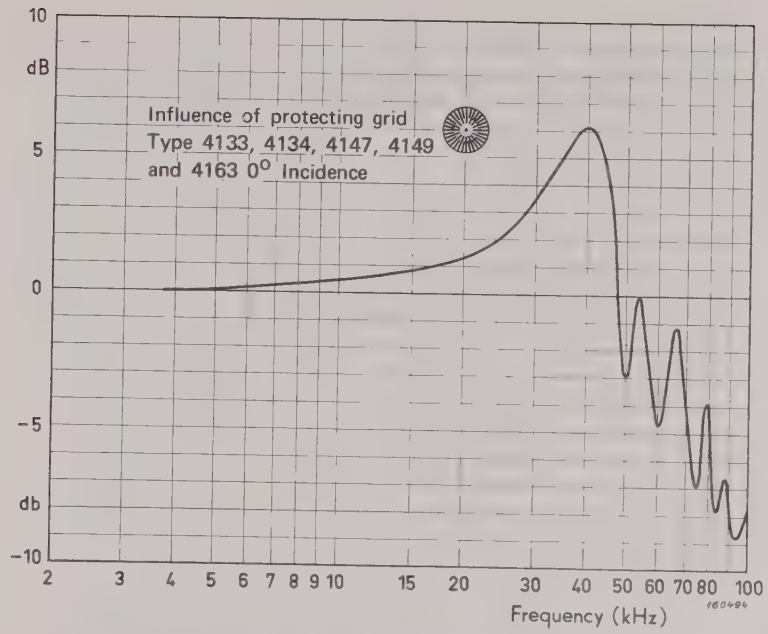


Fig.2.10. The influence of the protecting grid upon the free field response curve of the microphones. The grids are individually adjusted during manufacture in order to obtain this characteristic to within 0.2 dB up to 30 kHz and within 0.5 dB above

where S_o, S_{30} ... S_{180}, are the free field corrections at the respective angles of incidence. Fig.2.10 or a comparison between Figs.2.8 and 2.9 shows that the protecting grid influence is important for free field measurements. Since the microphones are calibrated with protecting grid, and because the diaphragm is extremely fragile, the protecting grid should only be removed in special circumstances such as coupler measurements, or measurements above 40 kHz.

2.4. DIRECTIVITY

Since the half-inch microphone cartridges have similar external dimensions when mounted on a preamplifier, the directional characteristics are identical up to 40 kHz. If measurements are required above this frequency,

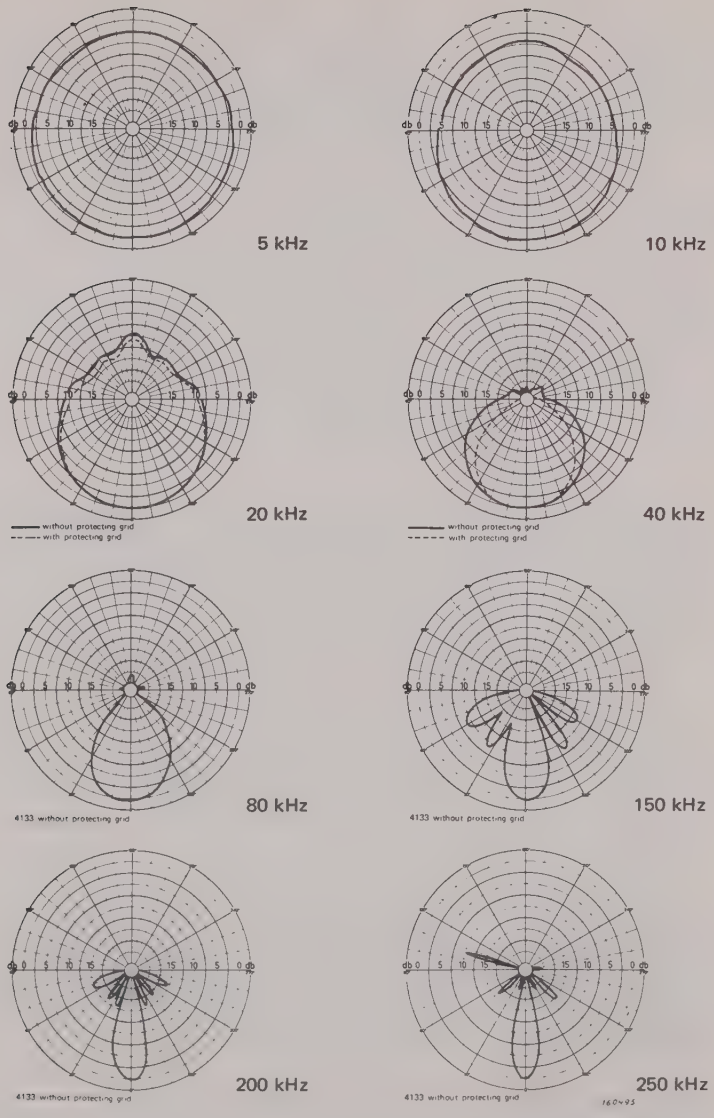


Fig.2.11. Typical directional characteristics of the half-inch microphones

it is best to use a smaller microphone such as the B & K 4135 or 4136 quarter-inch microphone or the 4138 eighth-inch microphone. The curves in Fig.2.11 can be considered typical of all three half-inch types. The omni-directivity can be improved by fitting the Nose Cone UA 0386 in place of the normal protecting grid. For further details see section 4.1.

2.5. DYNAMIC RANGE

The lower limit of the dynamic range is set by the noise level of the preamplifier when loaded with the microphone capacitance (nominally 18 pF for 4133, 4134, 4149 and 4163, 19.4 pF for the 4147). More precisely for the 4147, capacitance is given by

$$C = \frac{18}{1 - 7.10^{-5}\, p} + 1.4\ \text{pF}$$

where p = pressure difference across the diaphragm in pascals.

The preamplifier Type 2619 has a noise level below 40 μV for the frequency band 20 Hz to 200 kHz with 18 pF across the input. This sets the noise limit with a half-inch microphone to about 44 dB re 20 μPa in the linear range 20 Hz to 200 kHz. For analysis using third octave filters, the noise level is usually less than 7 μV, but is a function of frequency. For full information on this point, the manual for the preamplifier selected should be consulted.

The equivalent sound pressure level obtained in such a manner corresponds to the noise level of the preamplifier. It is usual to add 5 dB to the lower limit when quoting dynamic range, since a signal-to-noise ratio of 5 dB permits the exact determination of the acoustic signal noise level.

The upper limit of the dynamic range is set by the harmonic distortion.

For the 4133, 4134, 4149 and 4163 the limit is about 160 dB for 3% total harmonic distortion, as is shown in Fig.2.12. The distortion curve for the 4147 when used with a preamplifier and 200 volts polarization can be taken as similar to 4133, 4134, 4149 and 4163. With the Microphone Carrier System 2631, the distortion curves are as shown on Fig.2.12, distortion being less than 3% at 150 dB and 10% at 162 dB.

As polarization voltage is reduced, so the sensitivity of the microphone when used with a preamplifier is reduced also and the distortion of output signal will be reduced in proportion to the level of the output voltage. Also,

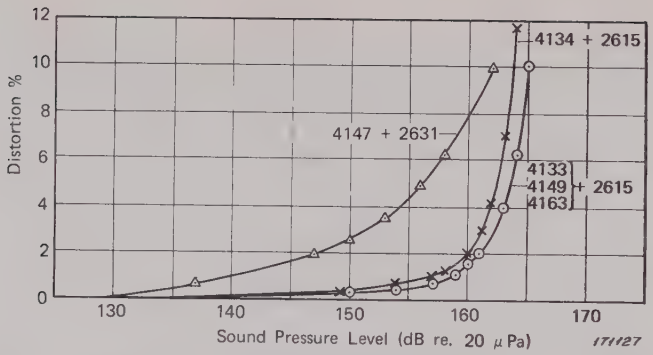


Fig.2.12. Typical harmonic distortion of the Microphone Cartridges 4133, 4134, 4149 and 4163 with Cathode Follower Type 2615 and of 4147 with Adaptor UA 0271 and Microphone Carrier System Type 2631

at frequencies that are above the resonance frequency of the microphone, the sensitivity will decrease, thus increasing the distortion limits. No damage will be caused to the cartridge if exposed to a sound pressure level of up to 174 dB with reference to 20 μPa. It is recommended that this limit is not exceeded.

2.6. PHASE CHARACTERISTICS AND PULSE RESPONSE

In the middle of the frequency range (say 20 Hz to 2 kHz), an increasing sound pressure produces a decreasing voltage output.

Above 2 kHz, the voltage output progressively lags further behind the pressure input, as shown by Fig.2.13 for the 4134 cartridge. The resonance frequency, which is defined by 90^{o} phase lag, is approximately 25 kHz.

At very low frequencies, the phase response will be influenced by acoustic elements in the microphone cartridge (particularly leakage through the equalization system) and by electrical elements at the preamplifier input. These result in a slight phase lead of voltage output with respect to the mid-frequency range.

Some examples of the 4134 or 4147 microphone response to a rectangular pulse input are shown in Fig.2.14 in comparison with other B & K

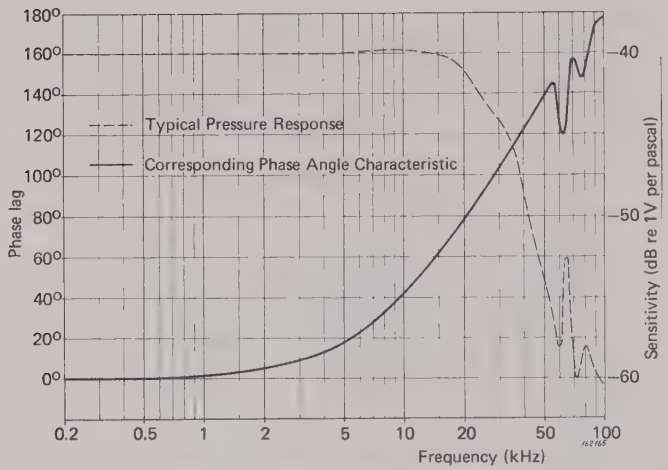


Fig.2.13. Pressure response phase angle characteristic for Type 4134. Type 4133, 4149 and 4163 has slightly less change in phase angle at higher frequencies. The dotted line indicates the frequency response

microphone sizes. The microphone was excited electrostatically by a positive rectangular pulse at a frequency of 2 kHz. The crest factor of the pulses (peak value/RMS value) was varied by varying the pulse duration, crest factors of 10, 5, 2 and $\sqrt{2}$ being produced by pulse durations of 5, 19, 100, and 250 μsec. In the lower part of Fig.2.14, pulses for 5, 19 and 50 μsec. (crest factors 10, 5 and 3) are shown with an expanded time base for the selected microphone types.

2.7. EQUIVALENT VOLUME

The equivalent volume of the five half-inch Microphone Cartridges 4133, 4134, 4147, 4149 and 4163, is approximately 0.010 cm^3 (10 mm^3) up to about 3 kHz. When dealing with closed cavity measurements (coupler measurements) it is convenient to express the acoustical input impedance of a condenser microphone in terms of the acoustical impedance of an equivalent air volume, V_e, by use of the equation

$$V_e = \frac{\gamma P_a}{j \omega Z_a}$$

where γ = ratio of specific heats (1.402 for air), P_a = ambient pressure, Z_a =

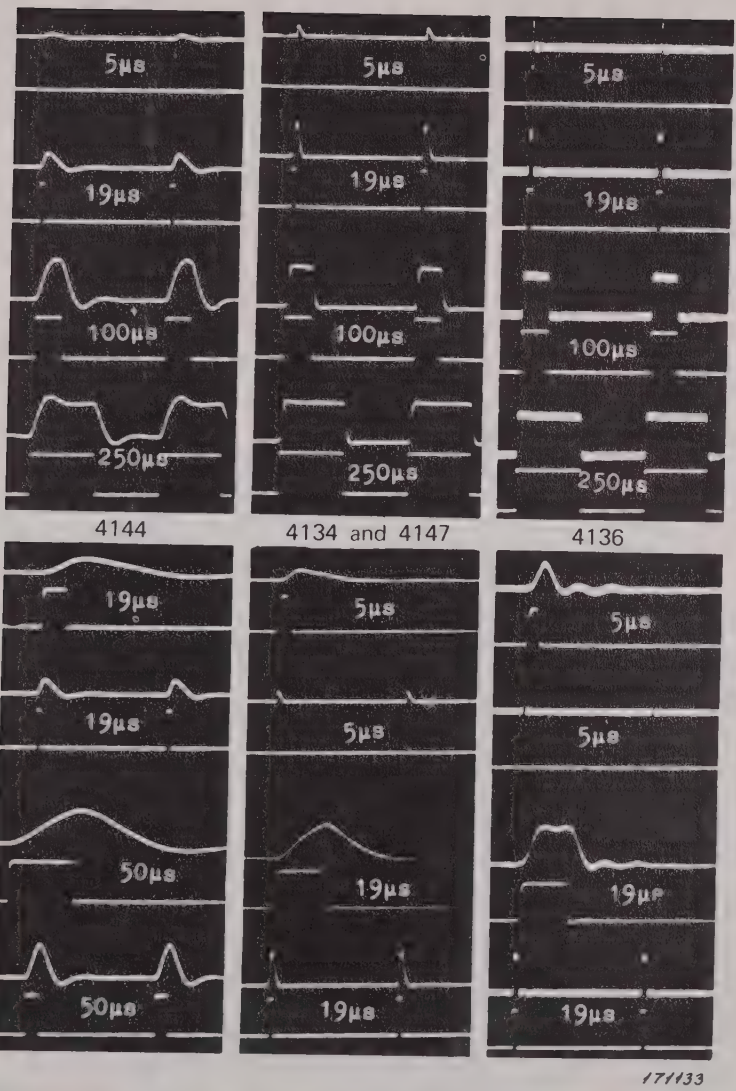


Fig.2.14. Examples of pulse response of the B & K microphone Types 4144 (one-inch), 4134 or 4147 (half-inch) and 4136 (quarter-inch)

acoustical impedance of the microphone, and ω = angular frequency (= $2\pi f$).

An example of the variation of equivalent volume with frequency for the 4134 is shown in Fig.2.15.

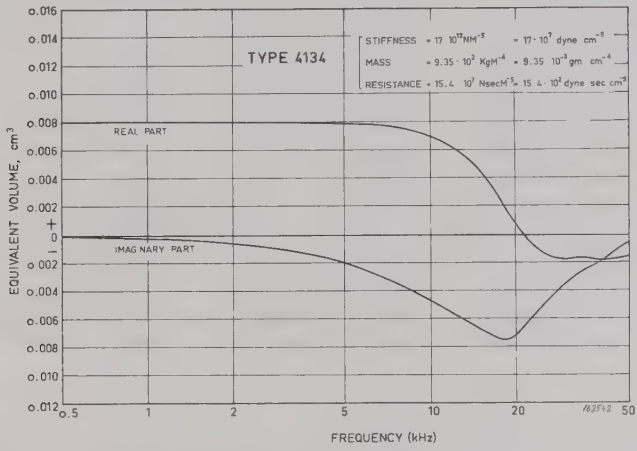


Fig.2.15. Equivalent volume and lumped Acoustical Parameters for the 4134

2.8. POLARIZED CARTRIDGE CAPACITANCE

Owing to the non-linearity of electromechanical coupling and to the effects of diaphragm movement, cartridge capacitance is slightly variable with frequency. Fig.2.16 shows typical cases for 200 volts polarization. The microphone capacitance at 250 Hz is measured individually for each microphone and is shown on its calibration chart.

If polarization voltage is reduced, so is the degree of electromechanical coupling. This results in microphone cartridge capacitance being independent of frequency, as is the case for the 4147 with 28 volts polarization and with the Microphone Carrier System. For the 4147, cartridge capacitance is given by:

$$C = \frac{18}{1 - 7.10^{-5}\,p} + 1.4\ \text{pF}$$

where p = pressure difference across the diaphragm in pascals.

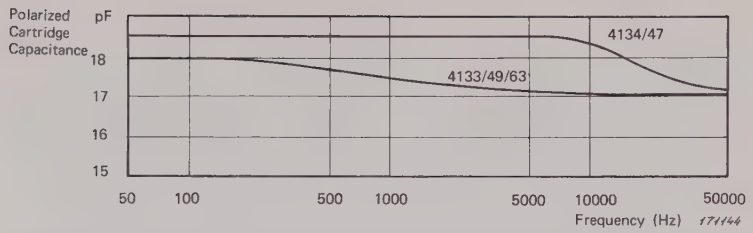


Fig.2.16. Variation of microphone capacitance with 200 volts polarization

2.9. INFLUENCE OF POLARIZATION VOLTAGE

In use with a preamplifier, the microphones are designed to operate with a polarization of 200 volts. B & K measuring amplifiers and analyzers having a special PREAMPLIFIER input socket are all adjusted to 200 volts polarization and this needs only very infrequent attention. Should it prove necessary, adjustment instructions are provided in the manual for the respective instrument.

If polarization voltage is varied from 200 volts, the electrostatic attraction between backplate and diaphragm is varied also. This means that the variation of sensitivity will not be a direct proportionality, as theory would suggest. Measured sensitivity variations are shown in Fig.2.17. Only a

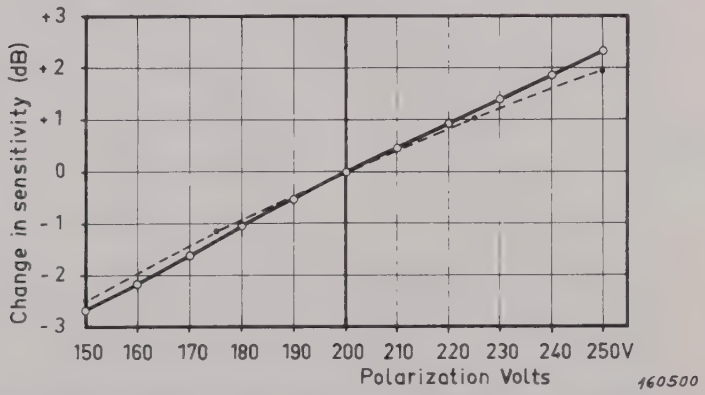


Fig.2.17. Microphone sensitivity versus polarization voltage at a frequency of 1000 Hz. The dotted curve gives the proportional value without taking the change in air gap into account

negligible change in frequency response will occur, as shown in Figs.2.18 and 2.19.

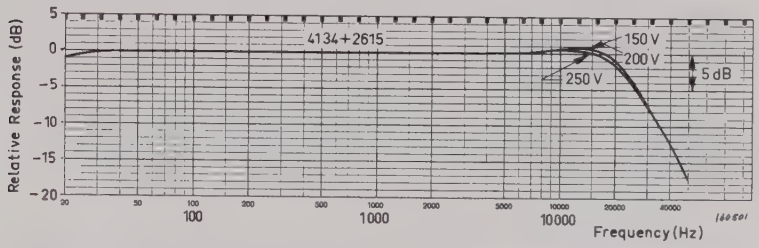


Fig.2.18. Pressure response curves of 4134 measured at three different values of polarization voltage. The recorder was adjusted to give the same deflection at 1000 Hz for all three curves

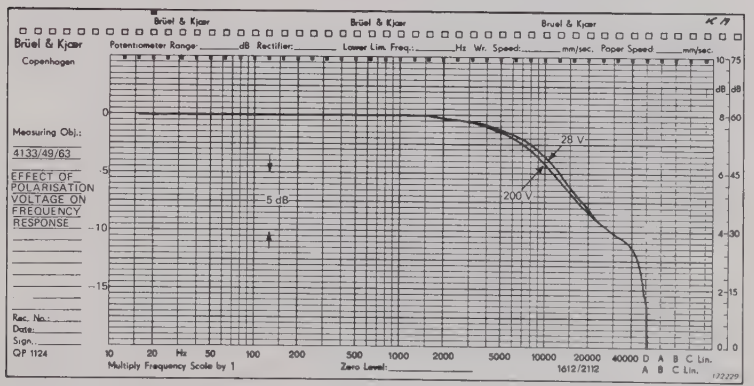
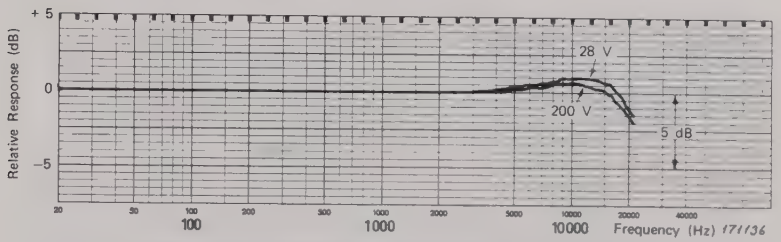


Fig.2.19. Effect of polarization voltage on frequency response of 4133, 4149 and 4163



g.2.20. Effect of polarization voltage on frequency response of 4147

The frequency response of the 4147 microphone is most conveniently measured by the same procedure as that used for the 4133, 4134, 4149 and 4163. However, the slight variation of frequency response with polarization voltage (Fig.2.20) makes it preferable to use 28 volts polarization to give a frequency response identical to that when the 4147 is mounted on the 2631 with adaptor UA 0271.

The maximum voltage which may safely be applied to any of the cartridges (as in the case when the microphone is used as a transmitter in coupler measurements) is 300 volts peak. This could be made up, for example, of 200 volts polarization and 100 volts peak signal input.

2.10. TEMPERATURE CHARACTERISTICS

Special care has been taken during the development and subsequent manufacture of the microphone cartridges to obtain a characteristic which, to a high degree, is independent of temperature. Fig.2.21 shows the variation of sensitivity with temperature for the normal and quartz coated microphones and Fig.2.22 shows the corresponding effects on frequency response. Fig.2.22a shows that a small decrease of approx. 2 dB can be expected around the resonant frequency (25 kHz) for the 4134, and Fig.2.22b shows an increase of approx. 2 dB around the resonant frequency (25 kHz) for the 4133, 4149 and 4163 when measurements are carried out at up to 150°C (300°F).

The insulating material used in the connecting cables of the B & K preamplifiers should not be exposed to higher temperatures than 100°C (212°F). The goose neck UA 0196 provided with Type 2619 can withstand temperatures of up to 150°C (300°F) on the housing or the goose neck. (250°C intermittently). The cartridges stand temperatures of up to 150°C (300°F) continuously, and 250°C (480°F) intermittently (but not without introducing a change in the sensitivity and frequency response characteristic). See also section 2.15.

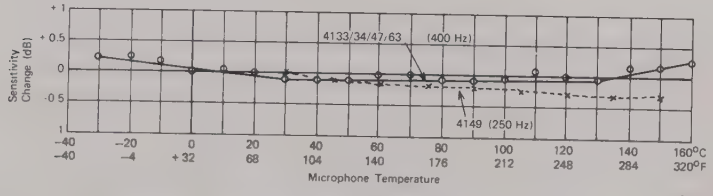


Fig.2.21. Variation of sensitivity with temperature

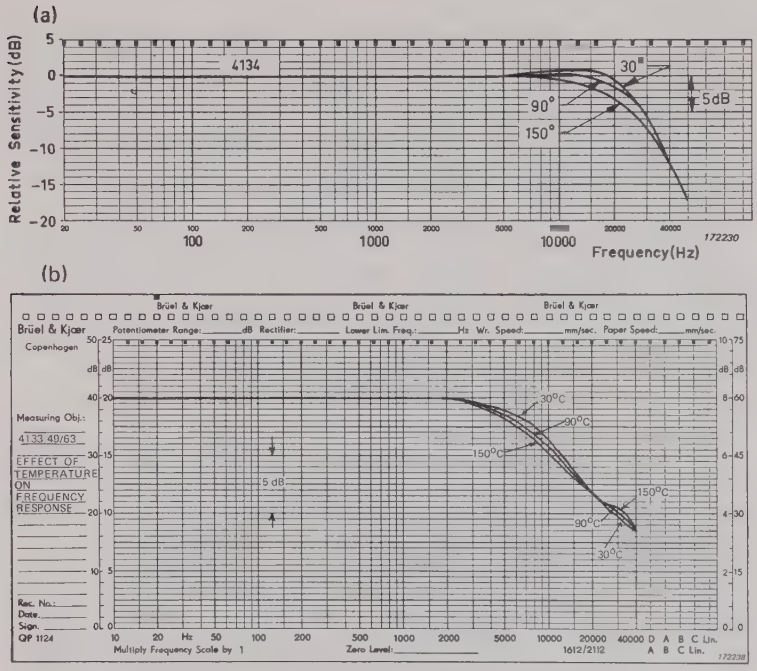


Fig.2.22. Typical response at various temperatures

In use in environments with varying temperatures, the 4147 will be more critical with regard to settling time because of the high resistance of the static pressure equalization vent.

2.11. INFLUENCE OF AMBIENT PRESSURE

For the 4133, 4134, 4149 and 4163 the sensitivity will be reduced by approx. 0.8% for a 10% increase in ambient pressure. Since the 4147 has a larger internal volume, the influence is smaller, being approximately 0.3% reduction in sensitivity for a 10% increase in ambient pressure.

For large changes in ambient pressure the frequency response of the microphone will be modified, especially towards the high frequencies since a change in mechanical damping is introduced. The frequency response at low ambient pressures for the 4133, 4149 and 4163 is shown in Fig.2.23a and

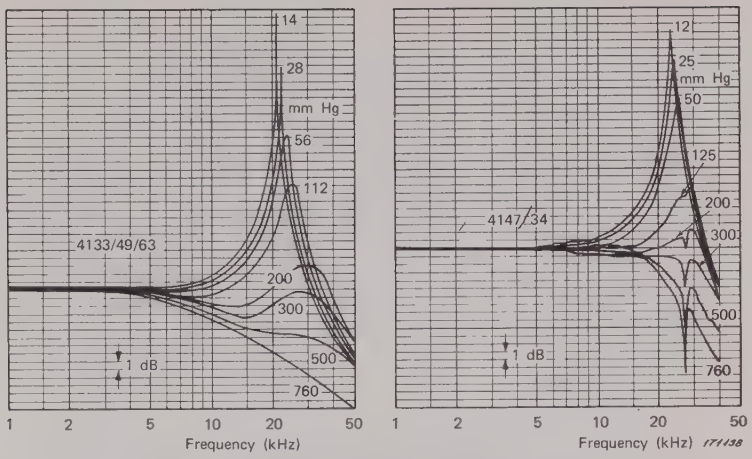


Fig.2.23. Effect of low ambient pressures on high frequency response a) for 4133, 4149 and 4163 b) for 4134 and 4147

for the 4147 and 4134 in Fig.2.23b. The effect of high ambient pressures is shown in Fig.2.24. For frequencies below the diaphragm resonance, the curve of Fig.2.25 shows in greater detail the influence of low static pressures on the 4134. Sensitivity on the linear part of the response curve varies by less than 1 dB within the pressure range 125 to 765 mm Hg.

Sensitivity at 1000 Hz is shown as a function of atmospheric pressure in Fig.2.26 for the 4133, 4134, 4149 and 4163. For 4147, the influence is approx. 40% of these values. For a detailed discussion of the performance under low pressure and varying altitude conditions, see B & K Technical Review No. 1–1960.

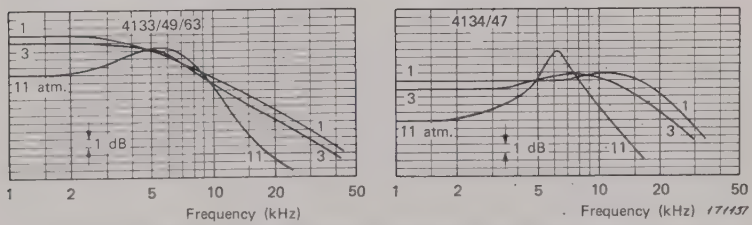


Fig.2.24. Effect of high ambient pressures on high frequency response a) for 4133, 4149 and 4163 b) for 4134

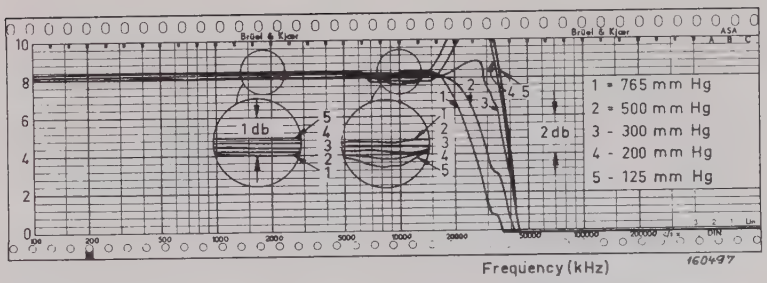


Fig.2.25. Mid-frequency response of a 4134 microphone at various low pressures

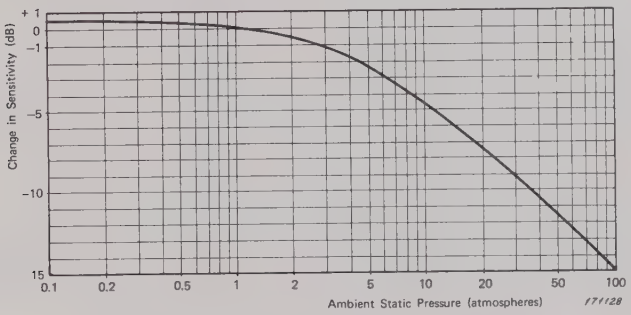


Fig.2.26. Variation in microphone sensitivity at 1000 Hz as function of ambient pressure for the 4133, 4134, 4149 and 4163

2.12. VIBRATION SENSITIVITY

The influence of vibration will depend on the direction in which it is applied to the microphone. When the force is acting in a direction which is parallel to the axis of symmetry (i.e. at right angles to the diaphragm) the sensitivity to vibration is mainly determined by the mass of the diaphragm and the air column on both sides of it. The microphone will be most sensitive to vibration acting in this direction, but due to the low diaphragm mass, the signal produced from an acceleration of 1 g is equivalent to a sound pressure level of 88 dB.

The sensitivity to vibrations acting at right angles to the axis of symmetry is much lower, and the critical parameter here is more often the

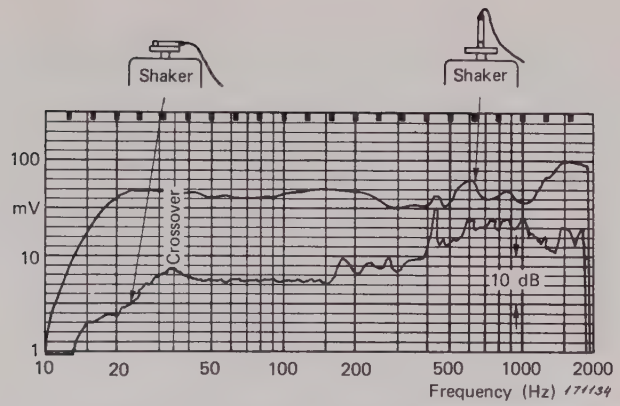


Fig.2.27. Output from a cathode follower and microphone subjected to a sinusoidal frequency sweep vibration test

preamplifier rather than the microphone. Fig.2.27 shows the response of the microphone cartridge with the Type 2615 Cathode Follower in a swept vibration test. Above 34 Hz, the acceleration level was maintained constant at 10 g. At lower frequencies, constant displacement was maintained with a continuous crossover level.

2.13. INFLUENCE OF MAGNETIC FIELDS

The influence of a magnetic field depends on its orientation with respect to the diaphragm of the microphone cartridge. With a magnetic field of 100 A/m aligned parallel to the axis of the microphone (which is the direction which has greatest influence on the cartridge), the induced output from the cartridge is approximately equivalent to a sound pressure level of 20 dB.

2.14. INFLUENCE OF HUMIDITY

Variations of ambient temperature may in some cases cause moisture condensation to take place between the diaphragm and the backplate of the cartridge. Then there is a temporary risk of electrical noise. When stable ambient conditions are regained, the condensed water will evaporate through the pressure equalization aperture. A description of these phenomena will be found in the B & K Technical Review No. 1—1960, p. 12—15.

It is therefore recommended that the microphone is not subjected to sudden changes in environmental temperature, or that a long settling time is allowed, particularly when the microphone is moved from a warm or moist environment to a colder location. In the absence of condensation, the relative humidity has practically no influence on the microphone sensitivity. Note that the use of dessicators during storage is not recommended.

If humidity is a problem, then use of the 4149 is strongly recommended. This microphone is designed to withstand the effects of humidity and possible subsequent corrosion both in terms of performance and life. These properties make it amply suitable for permanent outdoor installations such as in airport and vehicular noise monitoring systems. Such systems are manufactured by B & K and further details are available on request.

2.15. LONG TERM STABILITY

Microphone sensitivity may change during a long period of time even if no accident or mishandling has occured. This change is mainly brought about by a slight reduction in the diaphragm tension.

This rate of change of sensitivity can be accelerated at elevated temperatures. Tests have shown that at 150°C the rate of change is of the order of

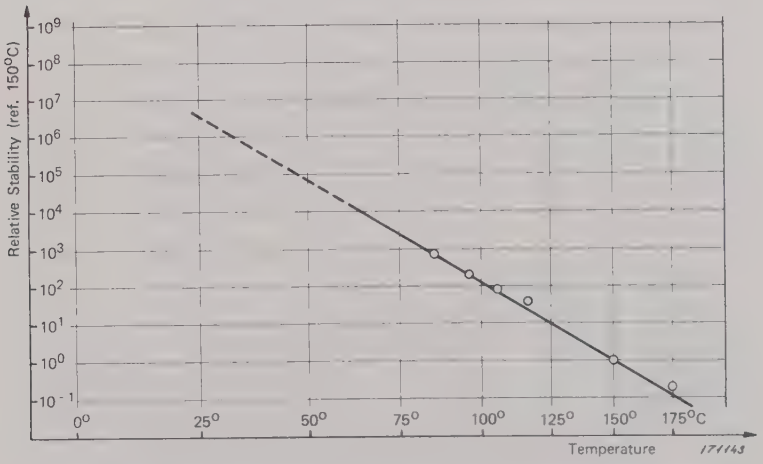


Fig.2.28. Long term stability of half-inch microphone cartridges

1 dB every two hours for the 4133, 4134, 4147, and 4163 and 1 dB every 0.33 hours for the 4149.

Fig.2.28 shows how the stability varies over a range of temperatures with respect to the stability at 150°C for all the microphones. By extrapolation the stability at room temperatures works out to be of the order of 1 dB every 900 years for the 4133, 4134, 4147 and 4163, and 1 dB every 150 years for the 4149.

Further information regarding this topic can be found in the B & K Technical Review No. 2—1969.

2.16. FREQUENCY RESPONSE IN A HELIUM ATMOSPHERE

When a microphone is moved from a normal air atmosphere to a helium atmosphere a change in the kinetics of the diaphragm occurs. These changes are reflected in the pressure response of the microphone as shown in Fig.2.29 for the 4133, 4149 and 4163, and Fig.2.30 for the 4134 and 4147.

Broadly speaking, the main amplitude limiting parameters of an oscillatory system such as in the microphone are as follows:

i) below resonance it is the stiffness of the diaphragm and the gas behind it,

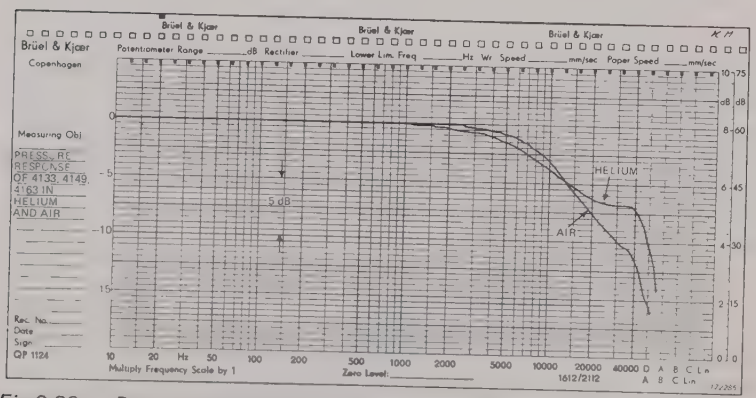


Fig.2.29. Pressure response of 4134 and 4147 in atmospheres of air and helium

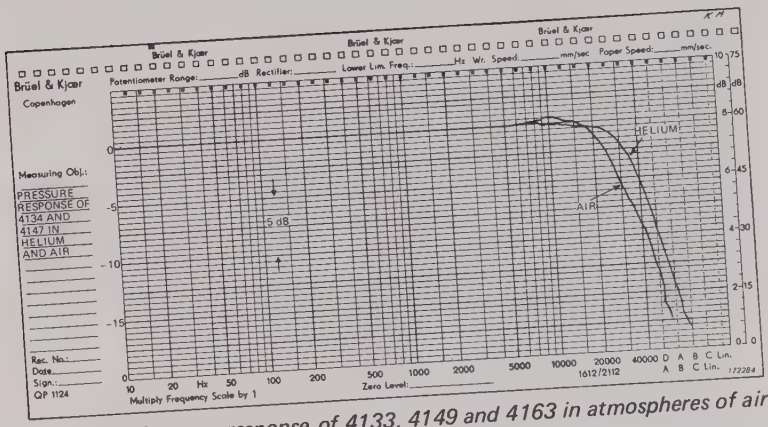


Fig.2.30. Pressure response of 4133, 4149 and 4163 in atmospheres of air and helium

ii) at resonance it is the viscosity (friction) of the gas behind the diaphragm,

iii) above resonance it is the inertia of the diaphragm and the gas behind it.

Figs.2.29 and 2.30 show the changes corresponding with (ii) and (iii) but not the very small change, approx. 4%, associated with (i).

3. CALIBRATION

3.1. GENERAL

The microphone cartridges are calibrated at the factory but recalibration may be desirable after special applications, e.g. after operation at high temperatures for long periods of time.

Common calibration methods include

a) Pistonphone
b) Sound Level Calibrator
c) Electrostatic Actuator

Both sensitivity at a fixed frequency and relative frequency response of the microphone must be calibrated, and therefore a combination of techniques is usually required to obtain a complete calibration.

3.2. PISTONPHONE TYPE 4220

The Pistonphone Type 4220 is especially recommended for system calibration. Each Pistonphone is individually calibrated, and the exact level of its reference signal is indicated on the chart which is supplied with the instrument. The Pistonphone Type 4220 (Fig.3.1) is a small, portable, battery driven unit weighing only 1.5 lbs, which is extremely well suited for field calibration. The Pistonphone produces, when fitted to a B & K microphone, a sound pressure level of nominally 124 dB re 20 μPa at 250 Hz,

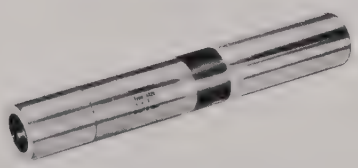


Fig.3.1. Pistonphone Type 4220

which is known with an error of less than ± 0.2 dB. This enables a direct sound level calibration of a meter scale to be made, and relative measurements can be taken with a very high accuracy. A barometer is supplied with the instrument for direct reading of ambient pressure corrections, together with adaptors for fitting to the different B & K microphones.

Full instructions can be found in the Pistonphone instruction manual.

3.3. SOUND LEVEL CALIBRATOR TYPE 4230

The Sound Level Calibrator Type 4230 (Fig.3.2) may also be used for system calibration. It is a pocket sized, battery driven unit designed for field use. The calibration signal of 1 kHz is produced at a pressure of 94 dB re 20 μPa. Since 1 kHz is the reference frequency for the standard international weighting networks (A, B, C, D, and linear), the Calibrator provides a common calibration point for all five networks.

Fig.3.2. Sound Level Calibrator Type 4230

The calibration accuracy is within ± 0.25 dB at 25°C and within ± 0.5 dB over the whole operating range 0 to 50°C.

Full instructions can be found in the Sound Level Calibrator instruction manual.

3.4. ELECTROSTATIC ACTUATOR TYPE UA 0033

The diaphragm of a Condenser Microphone may be influenced by electrostatic attraction in a way that is similar to the action of sound waves.

This may be done by placing a metallic grid in close proximity to the diaphragm and applying an alternating test voltage between them. Since the attraction is proportional to the square of the voltage, the test frequency is doubled.

The Electrostatic Actuator Type UA 0033 (Fig.3.3) is designed for use with half-inch, quarter-inch and eighth-inch microphones for investigation of the frequency response of the microphones.

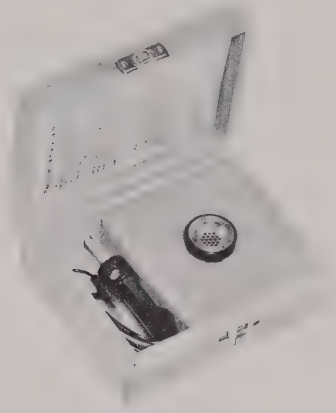


Fig.3.3. Electrostatic Actuator Type UA 0033

The Actuator is placed on the microphone cartridge, which should be held vertically. The Actuator has three glass studs which contact the periphery of the cartridge and provide spacing of approx. 0.5 mm between the Actuator grid and the diaphragm of the cartridge.

When using a Beat Frequency Oscillator Type 1022 the maximum available voltage of 120 V will provide an equivalent sound pressure level of about 80 dB at twice the oscillator frequency. Variations in the input signal measured in dB result in an equivalent sound pressure variation in dB of twice the input variation.

Since electrostatic pressure is not affected by ambient conditions, the actuator is an excellent method to use in determining the variations in microphone sensitivity under changing environments.

3.5. MICROPHONE CALIBRATION APPARATUS TYPE 4142

The Electrostatic Actuator is included in the Microphone Calibration Apparatus Type 4142, which is a set of equipment which can be used to provide calibration facilities for condenser microphones to the strictest laboratory standards. As well as providing facilities for reciprocity calibration of all B & K condenser microphones it can provide 800 volts polarization supply for application between the Actuator and the diaphragm in frequency response measurements. When an AC voltage is applied which is small compared with the 800 volts DC, the frequency of the signal applied to the microphone will be that of the AC input. With 30 volts RMS input, the signal level applied to the actuator produces the equivalent of a sound pressure level of approx. 94 dB at the microphone diaphragm. Full theory and instructions for the application of the Electrostatic Actuator are contained in the instruction manual for the Microphone Calibration Apparatus.

3.6. FACTORY CALIBRATION

3.6.1. Sensitivity

Microphone sensitivity is normally checked at 250 Hz using a specially maintained Pistonphone. In order to minimize the effect of production variations in microphone equivalent volume and the volume between the grid and the diaphragm, the internal volume of the Pistonphone is twice that of the Type 4220. Calibration level is therefore 118 dB. Accuracy of the calibration is regularly verified using microphones kept specially as standards, which in turn are verified by both factory calibrations and external authorities.

3.6.2. Frequency Response

The individual frequency response curves are measured by an electrostatic actuator method similar to that generally available using the Microphone Calibration Apparatus Type 4142.

3.6.3. Low Frequency Limit (–3 dB point)

Type 4147 microphones are individually checked that the Lower Limiting Frequency lies between 10^{-3} Hz and $5 \cdot 10^{-3}$ Hz. Since direct measurements at such low frequencies are extremely difficult and would take

considerable time, the time constant of the pressure equalization system (which determines the low frequency limit) is measured. The difference between the microphone internal pressure and the external pressure to which the diaphragm is exposed is:

$$\Delta P = P_o - P_i$$

If the external pressure is suddenly changed at time t = 0,

$$\Delta P = P_o - P_o (1 - \exp(-t/\tau))$$

i.e. $$\Delta P = P_o \exp(-t/\tau)$$

where τ is the time constant of the microphone's static pressure equalization system. Since the output voltage of the microphone when connected to the microphone carrier system is proportional to the external pressure, we can write

$$\Delta E = E_o \exp(-t/\tau)$$

where E_o is the voltage output at t = 0

Hence:

$$\frac{\Delta E}{E_o} = \exp(-t/\tau)$$

$$20 \log_{10} \left(\frac{\Delta E}{E_o}\right) = -\frac{20\,t}{\tau} \log_{10} e$$

$$\frac{\Delta E}{E_o} \text{ in dB} = -8.686 \frac{t}{\tau}$$

or if we write $\frac{\Delta E/E_o}{t} = V$ dB/sec, the slope of the microphone carrier system output plotted on a logarithmic scale:

$$\tau = -\frac{8.686}{V} \text{ sec.}$$

The lower limiting frequency −3 dB point (f_L) can then be obtained as in an equivalent electrical circuit as:

$$f_L = \frac{1}{2\pi\tau} \text{ Hz}$$

The principle of the factory calibration is shown in Fig.3.4. The microphone is fitted to the 2631 Microphone Carrier System via the Adaptor UA 0271 and the output of the Carrier System taken to a Level Recorder with 10 dB Range Potentiometer and set for DC response. Coupler volume is approx. 6 cm^3. A manometer is used to give a direct reading of the pressure change (where this is required) but principally to ensure that the pressure during the test remains constant. It provides the additional benefits of increasing the equivalent volume of the coupler, and suppressing the effect of heat conduction between the enclosed air and the inside walls of the coupler after the increment has been applied.

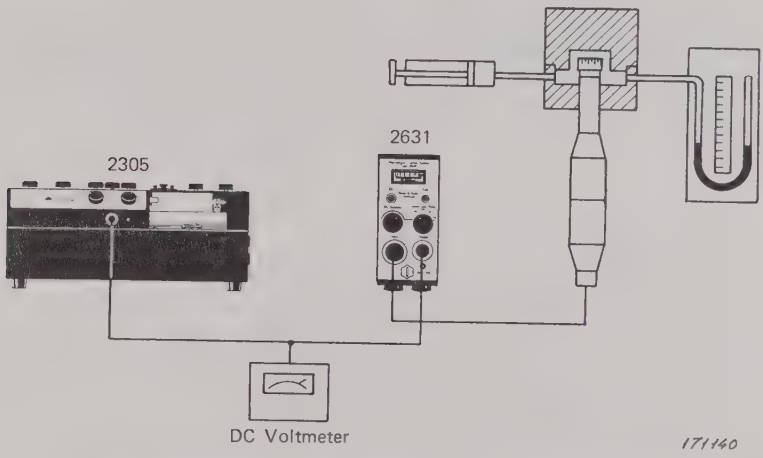


Fig.3.4. Calibration of microphone Lower Limiting Frequency

Before the pressure increment is applied, the DC level of the 2631 must be carefully balanced to zero in order to ensure that a linear decay curve results. The resulting decay curve is shown in Fig.2.7d from which the microphone's lower limiting frequency can be verified as $1.02 \cdot 10^{-3}$ Hz from its time constant of approx. 156 sec. Specifications for the 4147 demand a time constant for static pressure equalization between 30 sec. and 160 sec.

4. ACCESSORIES

4.1. NOSE CONE UA 0386

The Nose Cone UA 0386, Fig.4.1, is designed to substitute the protection grid of free field response half-inch microphones. It is extremely useful for measurements in low speed wind tunnels, ducts and other locations where noise measurements are required in the presence of high speed airflow

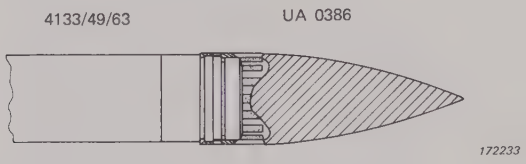


Fig.4.1. Sectional drawing of the Nose Cone

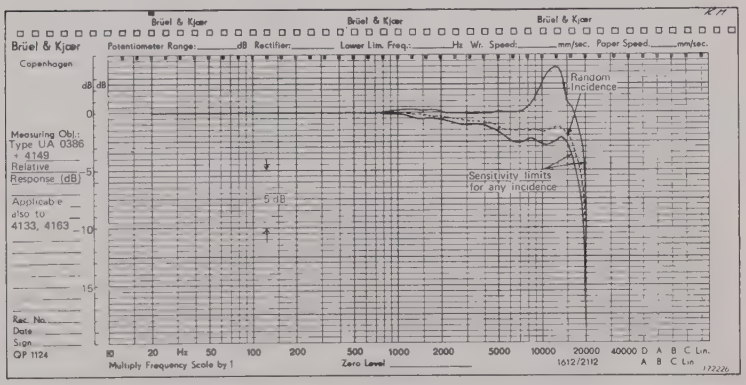


Fig.4.2. Free field response of a half-inch microphone equipped with nose cone

as well as in outdoor measurements in the presence of high winds. When the Nose Cone is used with a 4133, 4149 or 4163 microphone the omnidirectional properties are improved which make the Nose Cone useful also for still air measurements. See Fig.4.2. The free field corrections for the Nose Cone are given in Fig.4.3.

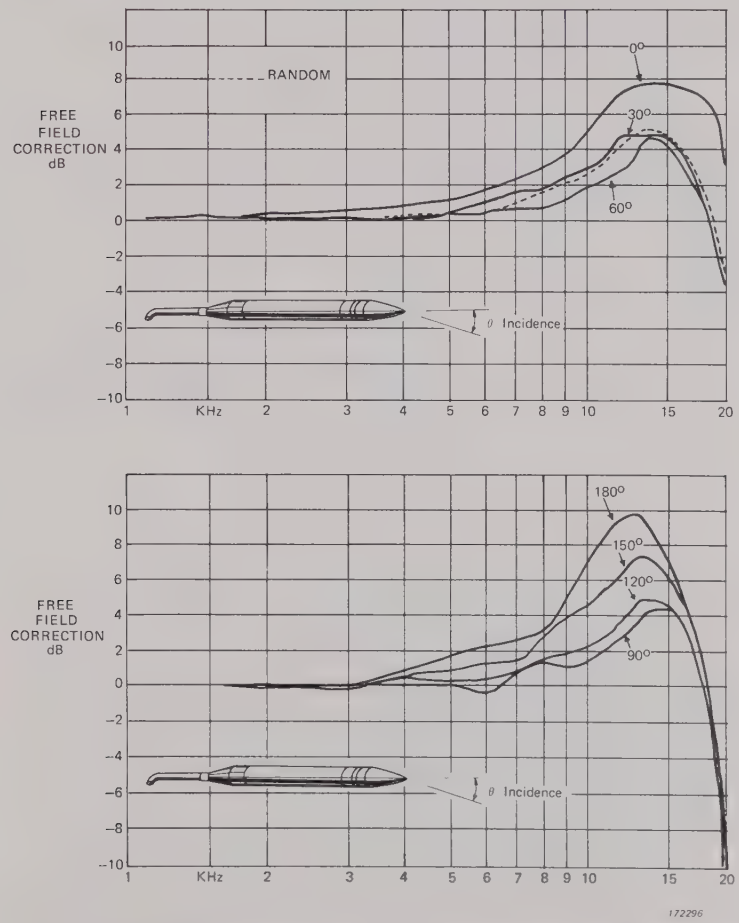


Fig.4.3. Free field corrections for the microphones with nose cone UA 0386 fitted

The construction of the Nose Cone is clearly seen from the sectional drawing in Fig.4.1. It is shaped to give the least turbulence in air flow. The fine wire mesh around the circumference allows sound waves to reach the microphone diaphragm, while the truncated cone inside the mesh reduces the air volume in front of the diaphragm. Fig.4.4 shows the wind-induced noise of a 4133 microphone fitted with a Nose Cone for wind speeds up to 160 km/h. Similar results can be expected using a 4149 or 4163.

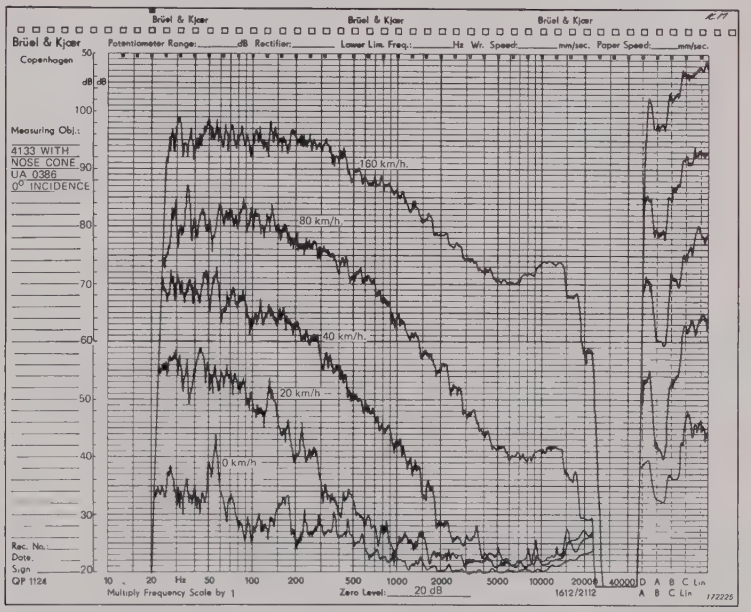


Fig.4.4. Induced noise levels as a function of windspeed and frequency. 0° incidence microphone 4133 with Nose Cone UA 0386

4.2. RAIN COVER UA 0393

The Rain Cover UA 0393, Fig.4.5 is designed to be mounted on B & K half-inch Condenser Microphones instead of the normal protection grid, and allows for permanent outdoor installations in that it has a built-in electrostatic actuator which permits remote calibration. The B & K screened cables AO 0037 and AO 0038 (not included) fit the microsocket of the actuator.

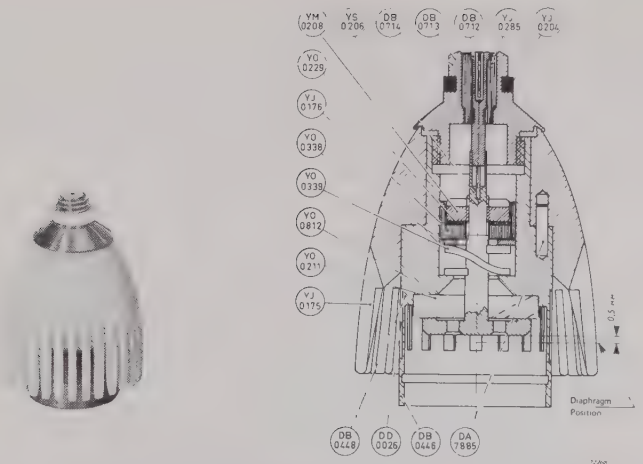


Fig.4.5. The Rain Cover UA 0393 with cable connector for feeding the built-in calibrator

The Rain Cover together with a Half-Inch Condenser Microphone Type 4133, 4149 or 4163 (4149 strongly recommended for all permanent outdoor applications) can be delivered factory calibrated to give an equivalent SPL of 90 ± 1 dB when 215 V AC is applied to the actuator terminal (80 ± 1 dB for 120 V AC).

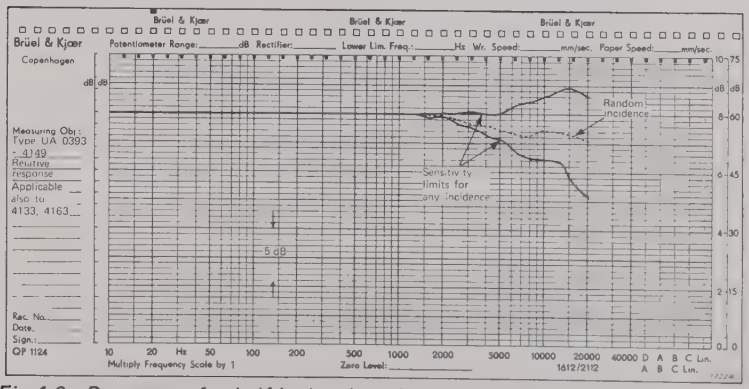


Fig.4.6. Response of a half-inch microphone 4139 fitted with a Rain Cover UA 0393

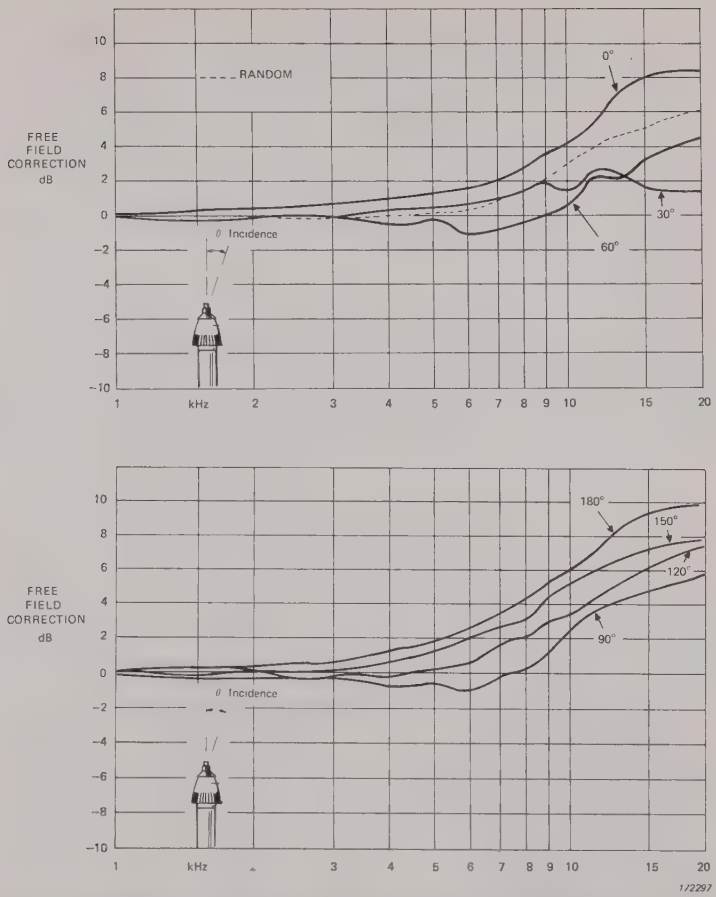


Fig.4.7. Free Field corrections for half-inch microphone fitted with a Rain Cover UA 0393

The Rain Cover also improves the omnidirectional characteristics of the microphone, see Fig.4.6. An extremely reliable permanent outdoor installation, for all extremes of weather, is a 4149 Outdoor Microphone fitted with a UA 0393 Rain Cover and UA 0308 Dehumidifier (§ 4.8) in conjunction with a UA 0381 Windscreen (§ 4.3). This combination complies with the directivity requirements of IEC R 179 Precision Sound Level Meters.

Free field corrections for the Rain Cover alone fitted to a half-inch microphone are shown in Fig.4.7.

The maximum working temperature of the UA 0393 is 150°C.

NB. The microphone is best protected when the associated preamplifier (Type 2615 or 2619) is permanently heated.

4.3. WINDSCREEN UA 0381

The windscreen UA 0381, Fig.4.8a is designed primarily for permanent outdoor microphone installations which also makes use of the Rain Cover UA 0393. Its construction consists of a spherical stainless steel welded wire frame covered with a layer of nylon net. On top is mounted a set of anti bird spikes designed to keep the windscreen free of perching birds and subsequent soiling.

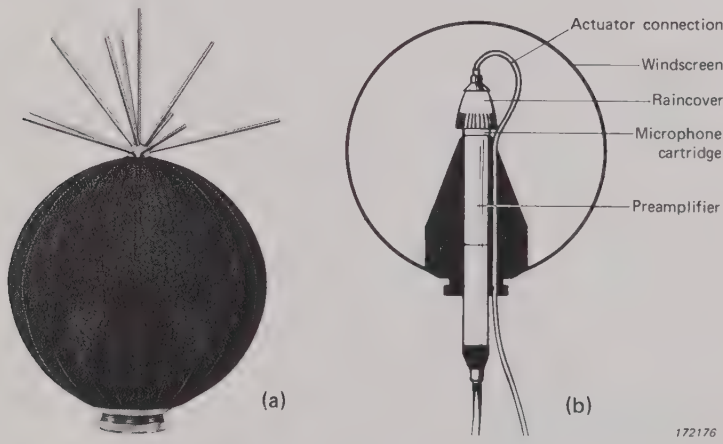


Fig.4.8. Windscreen UA 0381

The windscreen can be fitted with either a one-inch or half-inch microphone and its preamplifier. The microphone and the preamplifier assembly are inserted into a PVC cone inside the windscreen and held in position by a locking ring at the base of the cone and windscreen. In the case of the half-inch microphone and preamplifier, a PVC cylindrical insert is used to

hold them in position inside the main one-inch bore of the cone. The microphone should be mounted in the windscreen as follows:

a) One-inch Microphone
The whole cartridge only should emerge above the tapered end of the PVC cone.

b) Half-inch Microphone
The whole of the protection grid or Rain Cover only should emerge above the tapered end of the PVC insert.

In both cases the microphone and preamplifier assembly are kept electrically isolated from the steel frame of the windscreen.

When the windscreen is used with a Rain Cover UA 0393, provision is made for the actuator lead to be led down through the base of the PVC cone and locking ring, see Fig.4.8b.

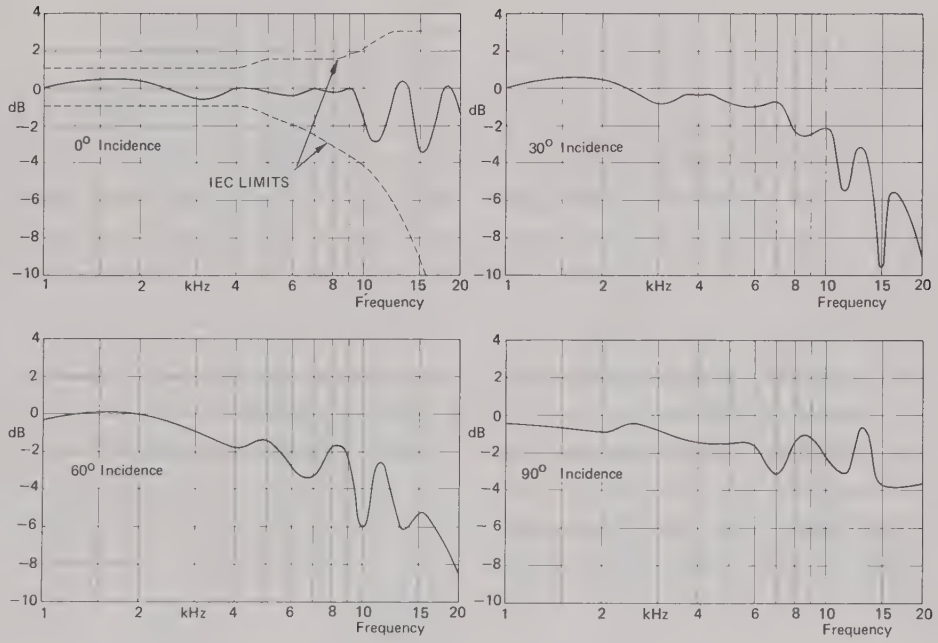
The windscreen gives an effective reduction in wind noise of the order of 10 dB or more for wind speeds of up to 150 km/h.

The performance of windscreen used in conjunction with a 4149 Microphone and a UA 0393 Rain Cover is shown in Figs.4.9 and 4.10. Fig.4.9 shows the omnidirectional characteristics of this combination which comply with the requirements of IEC R 179 Precision Sound Level Meters, and Fig.4.10 shows its induced noise levels as a function of wind speed and 1/3 octave band levels for 0^{o} and 90^{o} incidence.

Although a 4133 or 4163 microphone could be used instead of the 4149 to give similar performance, the 4149 is strongly recommended in cases where a permanent outdoor installation is required. This recommended combination forms part of the B & K Outdoor Microphone System, Type 4921, intended for all permanent installations. See Type 4921 Instruction Manual for further details.

4.4. WINDSCREEN UA 0237

The Windscreen Type UA 0237 is a ball of a specially prepared type of porous polyurethane sponge. It has a diameter of 9 cm and in use is simply pushed as far as it will go over the microphone and preamplifier. The free field correction curve of the microphone with this Windscreen fitted is shown in Fig.4.11.


4
2
0
dB
−2
−4
−6
−8
−10
0° Incidence
IEC LIMITS
1
2
kHz
4
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30° Incidence
60° Incidence
90° Incidence

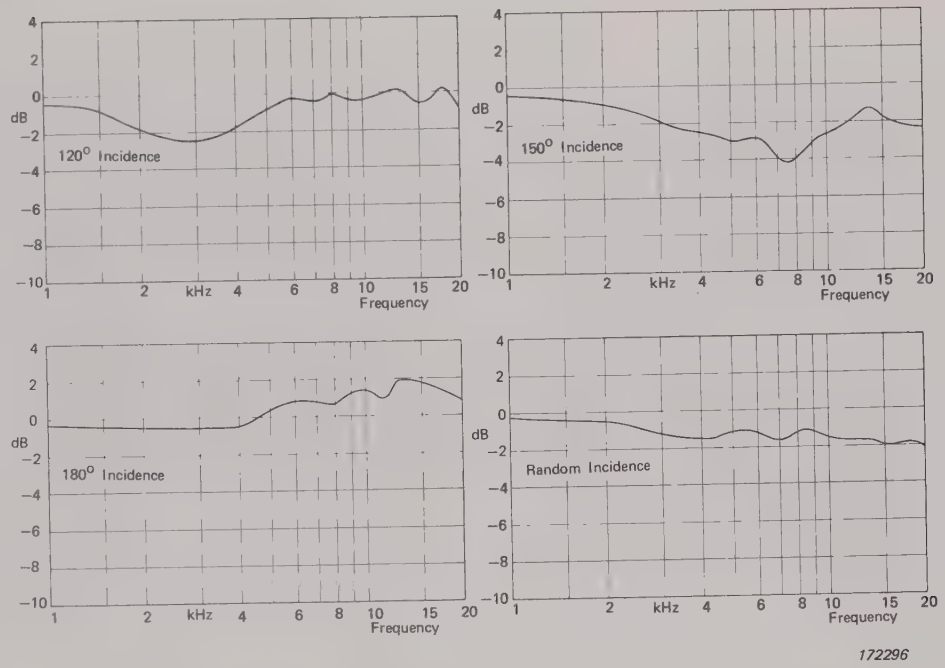


Fig.4.9. Omnidirectional characteristics of the Microphone 4149 fitted with a Rain Cover UA 0393 and Windscreen UA 0381

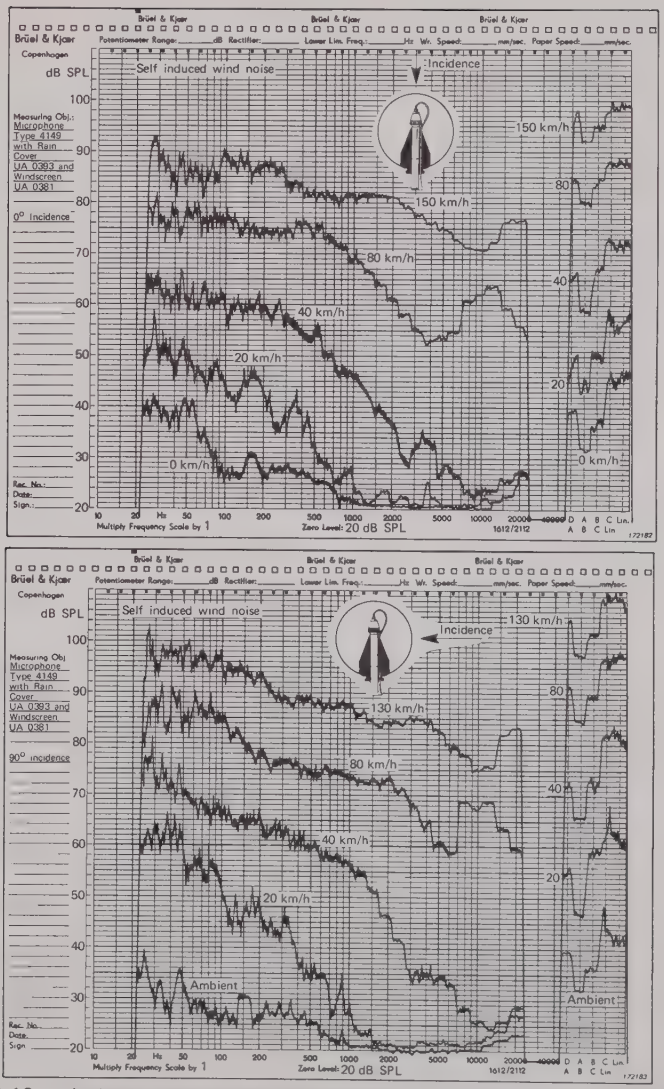


Fig.4.10. Induced noise levels as a function of windspeed and frequency. 0^{o} and 90^{o} incidence, Microphone 4149 with Rain Cover UA 0393 and Windscreen UA 0381

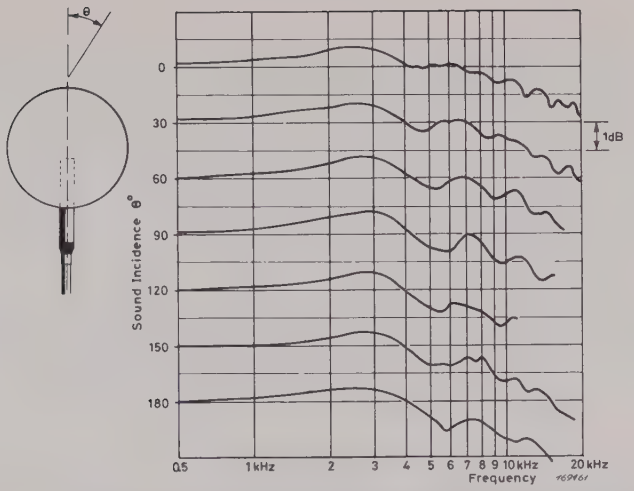


Fig.4.11. Increments to Free Field Correction curves due to Windscreen UA 0237

4.5. PROBE MICROPHONE KIT UA 0040

4.5.1. Purpose and Principle

Probe microphones can be used for a variety of applications such as measurements in the ear, measurement of sound insulating material and measurements within intricate machinery, as well as measurements in other normally inaccessible places, e.g. small ducts, furnaces, oilburners, etc. The requirements for length and width of the probes will vary with the application, but to obtain the best possible frequency characteristics, it is advisable to use a tube that is as short and wide as possible .

The probes have been compiled as a kit which allows the best possible choice of tube diameter and length for any particular application.

The performance of a probe microphone depends on the length and the width of the tube, the acoustical impedance of the microphone cartridge (equivalent volume of the cartridge) and the volume between the microphone diaphragm and the end of the tube terminating this volume. The tube diameter is normally very small compared to the wavelength, but the length of the tube will be the same or several times larger than the wavelength for a great portion of the audio-frequency range.

The response for a certain probe microphone will be determined by the attenuation of the tube, given by Beranek in "Acoustical Measurements" as:

$$\beta = K \sqrt{\omega} \cdot \frac{L}{d}$$

where K = a constant
ω = angular frequency
l = tube length
d = tube diameter

Furthermore, the ratio between the characteristic impedance of the tube and the impedance of the acoustical capacitor terminating the microphone end of the probe will change with frequency and cause a change in response (see Fig.4.12). Variations in frequency response may thus be expected for different tube dimensions, according to equation 4.1, as:

1. Linear response for low source impedance, low transmission loss and high impedance of the load as may be experienced for very short and wide tubes at low frequencies.

2. A 3 dB/octave drop in sensitivity at higher frequencies caused by transmission losses with medium size and length of tubes.

3. A 6 dB/octave drop in sensitivity at higher frequencies caused by the load of the capacitive coupler volume across the resistive part of the tube impedance with long narrow tubes (Fig.4.13).

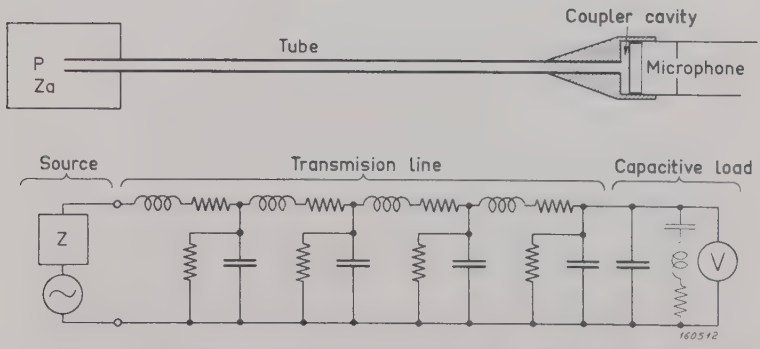


Fig.4.12. The probe microphone with equivalent electrical diagram

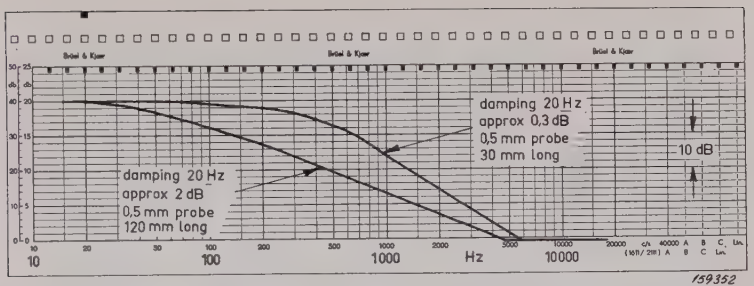
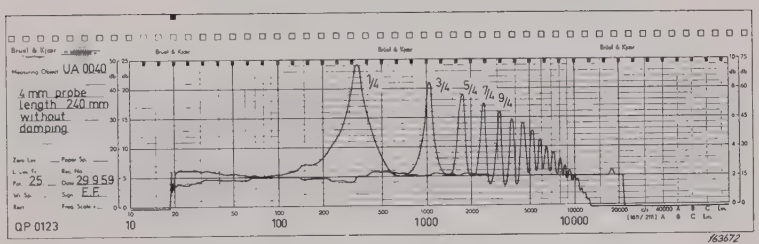


Fig.4.13. Typical frequency response curves for a narrow probe microphone (the recorder was adjusted to give the same deflection at 20 Hz in both cases)



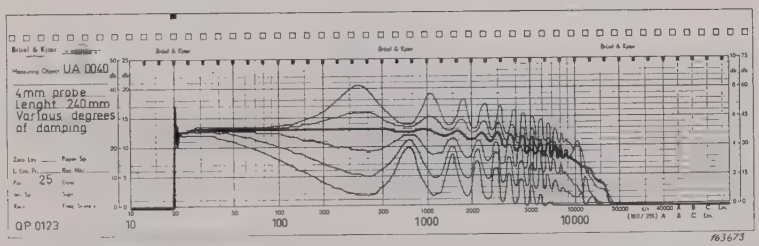


Fig.4.14. Recording showing the resonance modes of a probe microphone
a) Undamped probe
b) Various degrees of damping (the lower curves indicate too heavy damping)

4. A 9 dB/octave drop in sensitivity at higher frequencies caused by a combination of 2 and 3, especially at high frequencies (Fig.4.13).

5. A more or less pronounced resonance caused by the mass reactance of the tube in connection with the coupler cavity acting as a Helmholtz resonator with very short and wide tubes and large coupler cavities.

For tubes with 0.6 mm inside diameter or more, resonances will appear when the length of the tube is equal to 1/4 — 3/4 — 5/4 — 7/4 ... wavelengths, as in Fig.4.14. This is caused by the input impedance and the impedance of the tube with its termination. It is possible to obtain a smoother response by introducing damping material at the ends of the tube. In practice it is often sufficient to use damping at the front end only. It is then possible to adjust the damping in such a way that undulations on the frequency response are avoided at the low or high frequency end of the frequency characteristic, while some smaller undulations will show up over a limited range (Fig.4.19).

4.5.2. Description of the Probe Microphone Kit UA 0040

The Probe Microphone Kit Type UA 0040 (Fig.4.15) contains a set of four probe tubes with adaptors and tightening gaskets for mounting on the B & K half-inch microphones. The set is provided with accessories for calibration and adjustment of the probe damping in connection with the B & K Measuring Amplifiers, and with the tools necessary for cutting the probes.

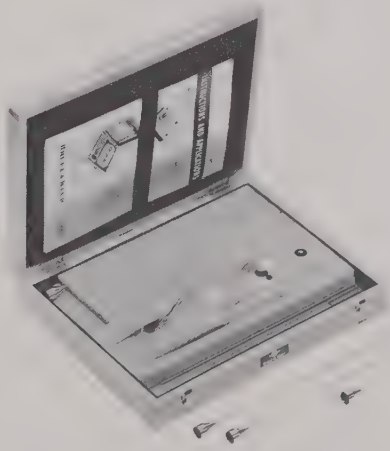


Fig.4.15. Probe Microphone Kit Type UA 0040

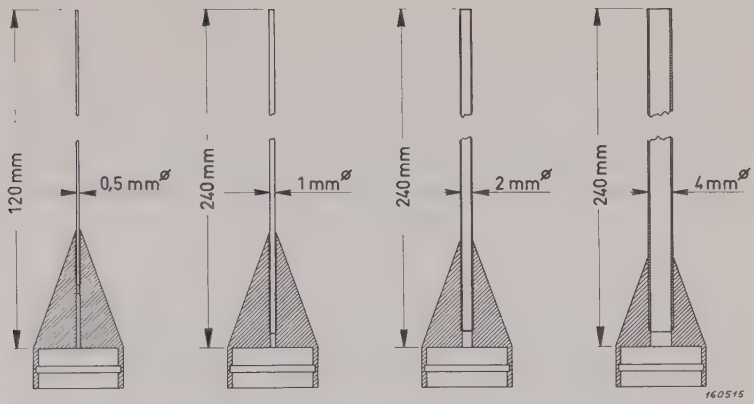


Fig.4.16. Sectional drawings of the probe tubes

The construction of the probes can be seen from Fig.4.16. The probe tubes are stainless steel, pressed into a conical adaptor.

4.5.3. Mounting

Mounting the probes on the microphone may be carried out either with or without the tightening gasket, as shown in Fig.4.17a and b. When mounted without the gasket as shown in Fig.4.17a, the probe adaptor is screwed carefully onto the microphone thread until the lower edge of the adaptor hits the collar on the microphone cartridge. The distance from the diaphragm to the end of the probe tube is then approximately 0.3 mm.

As shown in the figure, the pressure equalization circuit of the microphone is utilized in this case. This means that a change in static pressure in the probe tube will be transferred to the cavity behind the diaphragm, i.e. equalizing the pressure on both sides of the diaphragm.

When mounted with the tightening gasket as shown in Fig.4.17b, all dust should first be carefully removed from the microphone diaphragm and the gasket. The gasket is then laid into the adaptor with the raised edge against the microphone. The cartridge is screwed into the adaptor until the gasket just touches the diaphragm and is only lightly tightened.

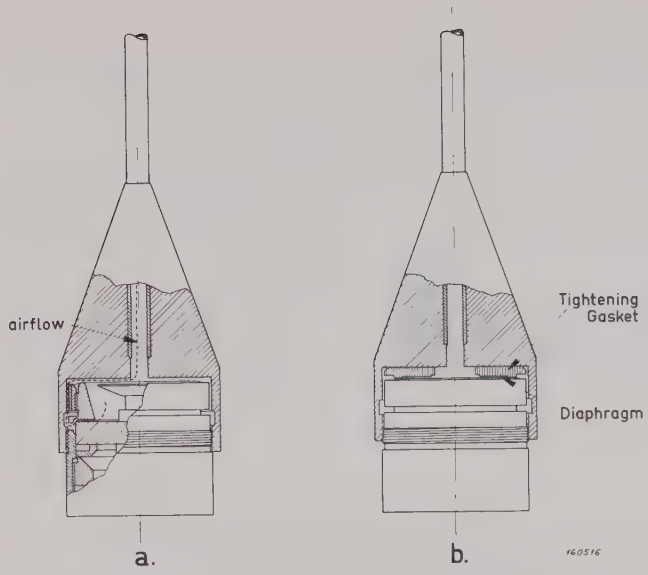


Fig.4.17. Probe tubes mounted on microphone
a) Utilizing the equalization circuit
b) Mounted with gasket

Note: The diaphragm is very fragile and should only be lightly touched with a piece of cotton wool or other very soft material. Any cleaning must be carried out with *extreme* care.

Mounted in this way the pressure equalization circuit is not utilized, while the air volume of the cavity in front of the diaphragm is considerably reduced. The air volume plus the equivalent volume of the microphone will in this case be lower than 0.02 cm^3 and thus ensures maximum frequency linearity of the probe microphone.

The reduction of the air volume has the effect of increasing the probe tube resonance frequency. The frequency of the fundamental resonance for the thinner tubes may be increased as much as one octave, extending the linear portion of the response curve.

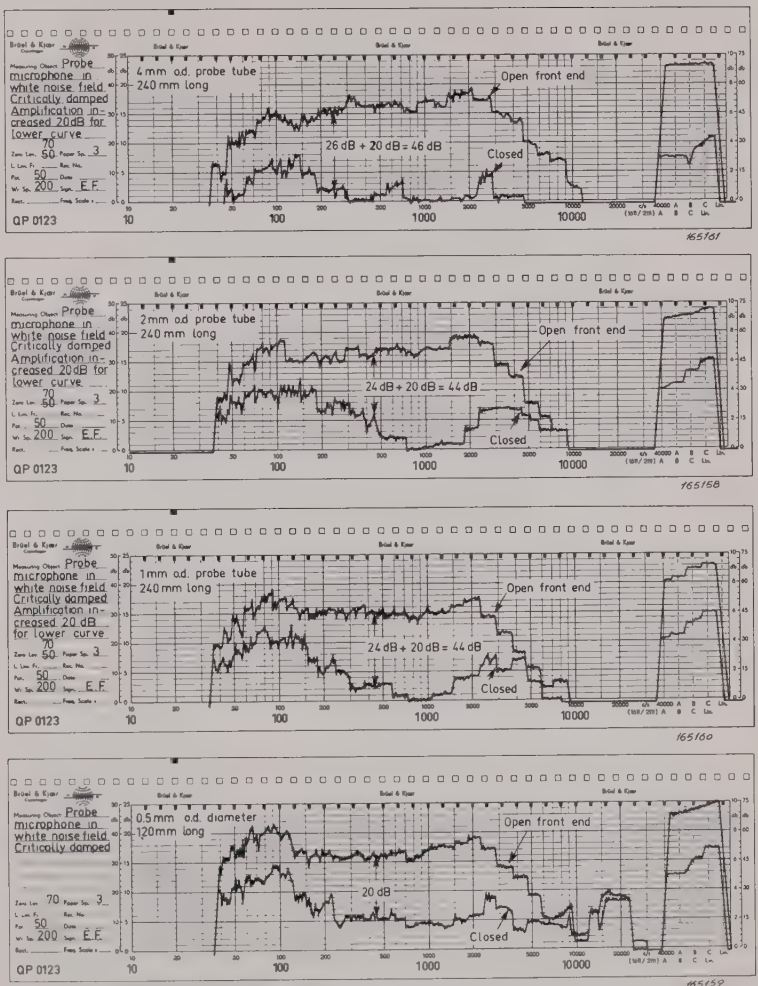


Fig. 4.18. Ratio of sensitivity of the probe microphone with open and closed tubes as a function of frequency
a) 4 mm probe tube
b) 2 mm probe tube
c) 1 mm probe tube
d) 0.5 mm probe tube

4.5.4. Measurement of Tubes Wall Transmission

A probe microphone must, to measure correctly, be more sensitive to sound pressure at the tube input than it is to sound transmission through the side walls due to non rigidity of the tube or leaks in the adapting piece to the microphone diaphragm. This transmission must be known for some applications, as for example, the measurement of the damping effect of ear cushions, where the sound pressure is measured outside and inside the ear cushion in order to determine the effect of the cushion itself.

The measurement of the probe microphones is easily carried out by measuring the difference in output from the probe microphone, when placed in a sound field with and without the tube input being blocked.

In Fig.4.18 is shown the ratio as obtained in third octave bands when the complete microphone is exposed to a sound field consisting of white noise. The upper curves indicate the sensitivity with open probe tube end, while the lower curves indicate the sensitivity with the end probe tube closed. The amplification of the measuring equipment was increased by 20 dB when the lower curve was taken, with a view to improving legibility (except for the 0.5 mm tube). It is therefore necessary to add 20 dB to read off the difference in sensitivity. The curves are obtained with a probe of full length which is well damped. For shorter tube lengths the performance will be the same or better.

4.5.5. Calibration and Damping Adjustment

Calibration consists of the determination, at all frequencies of interest, of the change in microphone sensitivity due to the introduction of the probe (i.e. the frequency response of the probe). Accurate determination of this frequency response is easiest by the closed coupler technique described below. A special 2 cm^3 coupler is supplied with the kit for this purpose. However, this calibration will be valid for use in a free sound field only if the acoustic impedance of the probe microphone is much greater than the acoustic impedance of the 2 cm^3 coupler. This condition may be verified by measuring the change in sound pressure in the coupler cavity with the probe microphone introduced, and with the hole in the coupler closed by (for example) a finger instead of the probe microphone. If more than about 3 dB variation is noted, it is necessary to make the calibration in a larger coupler or in a free field.

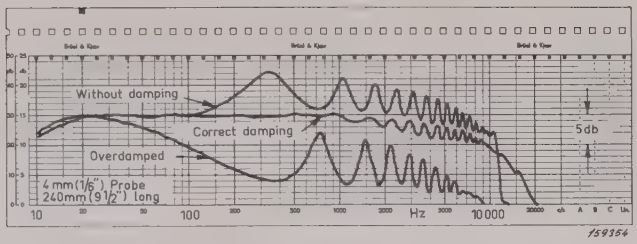


Fig.4.19. Example of a frequency response for a probe microphone with different degrees of damping

Free field calibration is carried out by measuring the response in front of a suitable sound source, such as the Artificial Voice Type 4219, or, for lower frequencies, the small earphone included in the probe kit, with the condenser microphone alone and with the probe microphone exactly at the same point. The distance from the sound source should be at least 5 cm (2 in) and the incidence should be 90° (i.e. sound wave propagation perpendicular to the microphone in both cases). The probes should be correctly "damped" in order to obtain the best possible frequency response as shown in Fig.4.19. (The 0.5 mm diameter tube needs no extra damping, as is seen in Fig.4.13).

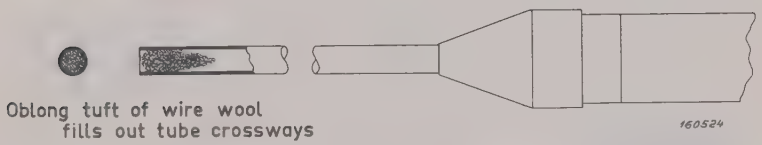


Fig.4.20. Damping by means of wire wool applied in the probe tube

The damping is obtained by means of the damping material supplied with the probe kit. The material is fine steel wool of a normal commercial quality, which is found suitable for the purpose. To carry out damping, make a small oblong tuft of steel wool, not too firmly compressed, and insert in such a manner that the tube is filled out with damping material. For the 1 mm tube it may also be convenient to use a small piece of the 0.5 mm tube as the damping material.

The degree of damping will mainly depend on the compactness of the filling. The effect on the frequency response curve may be readily recorded by means of the arrangement of Fig.4.21, and by a trial and error method an almost linear characteristic can be obtained over a wide frequency range, depending on the probe dimensions. The method follows in section 4.5.6.

4.5.6. Probe Microphone Frequency Response

Arrangement of equipment suitable for recording the frequency response of the microphone with probe tube fitted is shown in Fig.4.21. This arrangement employs the Beat Frequency Oscillator Type 1022, two Measuring Amplifiers 2606 (Type 2608 could also be used), the Level Recorder 2305, and the coupler and sound source supplied with the Probe Kit UA 0040. This sound source is suitable for use up to 5 kHz.

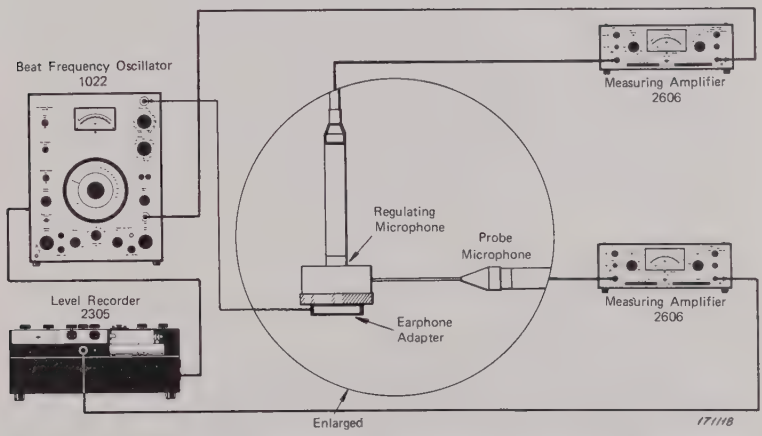


Fig.4.21. Calibration arrangement with automatic regulation of the sound pressure in the coupler

With the system shown in Fig.4.21, the signal from the Regulating Microphone is fed back to the Compressor circuit of the Oscillator, which regulates to a constant sound pressure level in the coupler. The Level Recorder therefore plots the voltage output for a constant sound pressure level input to the Probe Microphone. A mechanical drive between the Level Recorder and the Oscillator ensures frequency synchronism.

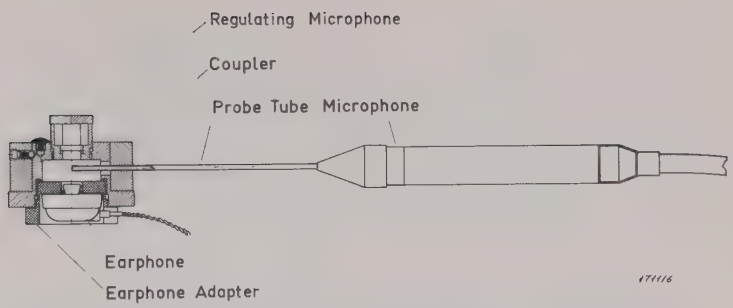


Fig.4.22. Location of Probe Tube in Coupler

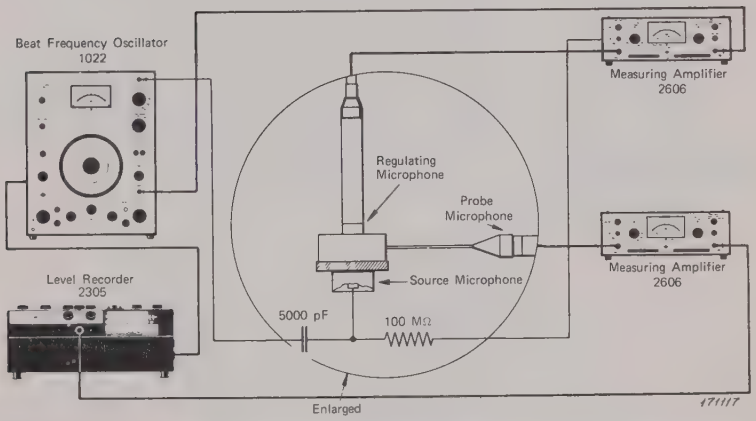


Fig.4.23. Arrangement using a Condenser Microphone Cartridge 4144 as sound source, and employing a regulating microphone and compressor circuit

Fig.4.22 shows a sectional drawing of the coupler with the probe tube and sound source in position. The probe tube should be inserted so that the tube end is on the axis of symmetry. For calibration frequencies above about 4 kHz, the sound source provided with the Probe Microphone Kit should be replaced by a 1 inch Condenser Microphone Cartridge Type 4144. This extends the useful frequency range to about 7 kHz. Because of the large diaphragm area, this microphone will give a more uniform sound field inside the coupler than could be obtained with a half-inch microphone. For

this reason the half-inch microphone is not recommended as a sound source for the coupler calibration. In spite of its uniform frequency response to approx. 20 kHz, the sound distribution inside the coupler is not sufficiently uniform to permit an accurate calibration. See Fig.4.23.

If the Microphone Calibration Apparatus Type 4142 is also available, it provides a very convenient mounting and power supply for the source microphone. Connections are as shown in Fig.4.24.

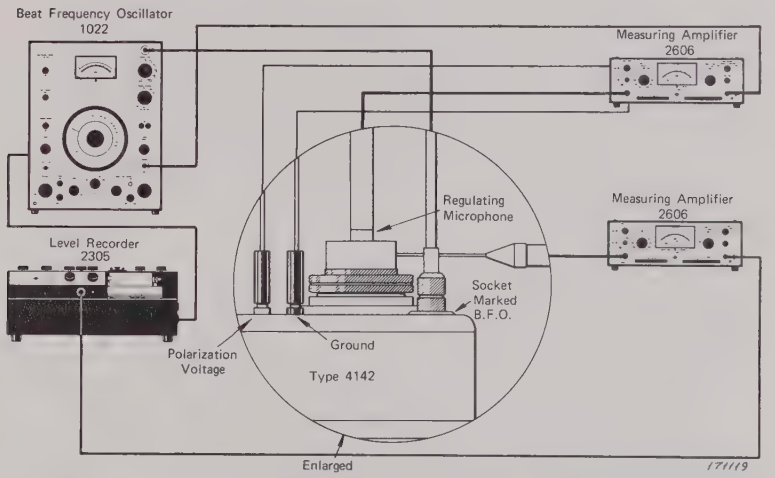


Fig.4.24. Calibration by means of Type 4142 with regulating circuit applied

4.5.7. Parts List for Probe Microphone Kit

		Part Number
1	0.5 mm outside diameter probe	DB 0240
1	1 mm outside diameter probe	DB 0241
1	2 mm outside diameter probe	DB 0242
1	4 mm outside diameter probe	DB 0243
1	spare tube for 0.5 mm diameter probe	YA 0051
1	spare tube for 1 mm diameter probe	YA 0052
1	spare tube for 2 mm diameter probe	YA 0053
1	spare tube for 4 mm diameter probe	YA 0054
1	4 teflon gaskets	YJ 0070

1 calibration coupler ..... DB 0260
1 earphone with plugs ..... HT 0003
1 PVC earphone adaptor ..... YJ 0084
1 mechanical adaptor for mounting 1/2" cartridge as exciter ... DB 0225
1 dummy microphone consisting of DB 0262 screwed into .... DB 0264
1 special tong ..... QA 0022
1 file ..... QA 0017
Some steel wool No. 0 and emery paper No.320.

4.6. FLEXIBLE ADAPTORS UA 0122 and UA 0123

The Flexible Adaptors UA 0122 and UA 0123 have been designed for use with the B & K half-inch microphones as well as the quarter-inch microphones (4135 and 4136). They consist basically of a flexible rod and three mechanical mounting pieces, see Fig.4.25. At one end of the rod is placed a mounting arrangement for attachment to a Cathode Follower Type 2615 (or Preamplifier 2619) and at the other end the microphone cartridge itself can be mounted. UA 0122 allows side mounting of the cartridge while UA 0123 is designed for end mounting.

Fig.4.25. Flexible Adaptors UA 0122 and UA 0123

Both Adaptors make use of the B & K double screening system which reduces the input capacitance, and thus its influence on the microphone characteristics, to a minimum. The increase in input capacitance caused by the Flexible Adaptor is of the order of 2 pF. Insulation materials used are teflon and silicone treated rubber, and the inner of the two screens is of a special mini-noise type.

The quarter-inch microphones can be mounted directly on the Adaptors while the half-inch microphones require the use of a mechanical conversion arrangement, which is supplied with the Adaptor. Also supplied with the Adaptor are two flush mounting pieces, one for the quarter-inch microphone and one for the half-inch microphone. The flush mountings are designed with the smallest possible heights.

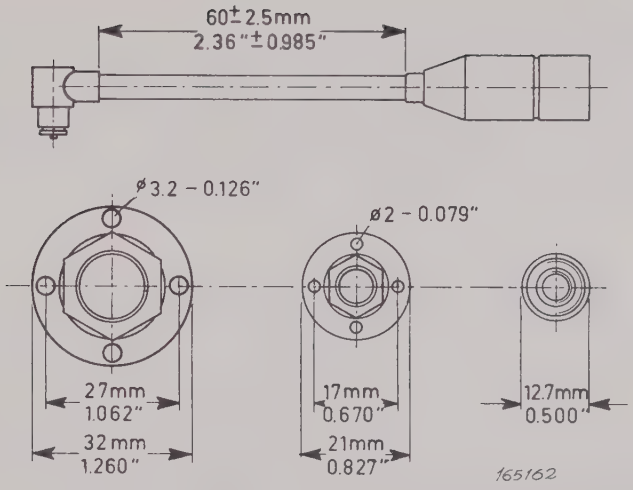


Fig.4.26. Sketch of the flexible rod and the flush mounting contained in UA 0122

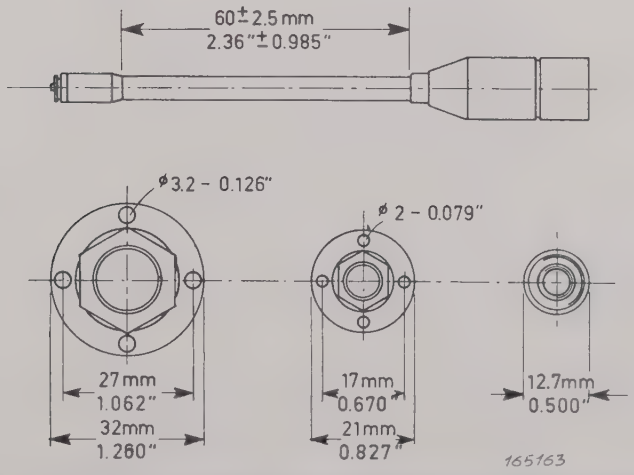


Fig.4.27. Sketch of the flexible rod and the flush mountings contained in UA 0123

When the microphone and Flexible Adaptor are mounted on a preamplifier, it is recommended that the complete arrangement is calibrated by means of a Pistonphone Type 4220 if accurate measurements are to be made.

Cross sectional drawings of the Adaptors are shown in Figs.4.26 and 4.27.

4.7. COUPLER MOUNTINGS

By means of the Mechanical Adaptor DB 0225, the half-inch microphones may be mounted in the different B & K couplers which are designed for the one-inch microphones. The mechanical adaptor DB 0225 gives the Cartridges 4133, 4134, 4147, 4149 and 4163 the same external dimensions as the Cartridges 4144 and 4145. Three couplers corresponding to the specification of the American standards are available:

(1) 2 cm^3 Coupler Type DB 0138 (Z.24.9.1949 and IEC)
(2) 6 cm^3 Coupler Type DB 0909 (N.B.S. type 9A)
(3) 6 cm^3 Coupler Type DB 0161 (Z.24.9.1949, type 1)

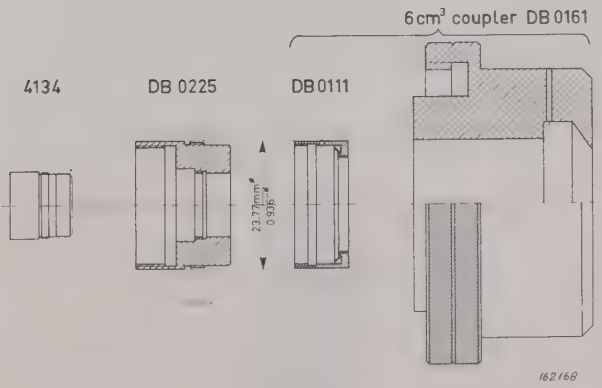


Fig.4.28. Mounting of a half-inch microphone in the 6 cm^3 coupler corresponding to the American Standard Z 24.9.1949

For reciprocity calibration using the Microphone Calibration Apparatus Type 4142, the half-inch microphones must be fitted with adaptor DB 0225 if the 20 cm^3 or 3 cm^3 couplers are used. A 0.3 cm^3 coupler, to which the half-inch microphones can be fitted directly, is also available as a part of the Type 4142. All are described in the instruction manual for 4142.

By screwing the Coupler Adaptor Ring Type DB 0111 on the one-inch or half-inch microphone + DB 0225 (Fig.4.28), a 0.936 in (23.77 mm) diameter microphone is obtained which allows measurements to be made in complete agreement with the standards. See the manual for the Artificial Ear Type 4152.

Note: The gas contained in the coupler also fills the microphone cartridge. If the gas density differs markedly from that of air at atmospheric pressure, a change in damping and in frequency response is to be expected.

4.8. DEHUMIDIFIER UA 0308

The Dehumidifier UA 0308, Fig.4.29, is designed to be mounted between a 4147, 4149 or 4163 microphone and its preamplifier. It contains silica gel which effectively dries the air used by these microphones for pressure equalization. Note these microphones have the pressure equalization holes led out to the back of the quartz insulator especially for this purpose. The Dehumidifier will be quite ineffective on the Microphones (4133 and 4134) which have their pressure equalization holes led out to the side of the cartridge.

The Dehumidifier should be used in all applications where there is a risk of water condensing inside the microphone. A small aperture in the Dehumi-

Fig.4.29. Dehumidifier UA 0308

difier case allows inspection of the state of the silica gel as it changes colour from blue in a dry state to red in a wet state. The silica gel can be dried out by heating for some hours at a temperature of 100° C or longer at lower temperatures. When used in 100% RH it requires drying approximately once a month.

Fig.4.30 shows a simplified sectional diagram of the Dehumidifier with the microphone mounted. The influence of the Dehumidifier on the signal is less than 0.3 dB.

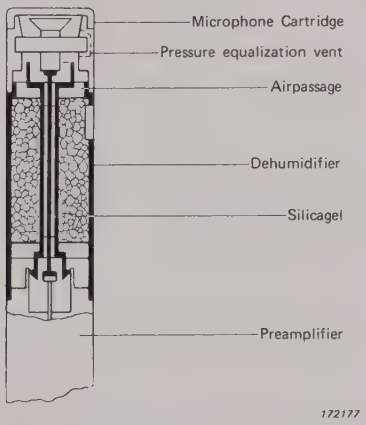


Fig.4.30. Cross sectional view of Dehumidifier mounted between pre-amplifier and microphone

5. SPECIFICATIONS

5.1. TYPE 4133, AND 4163 FREE FIELD RESPONSE MICROPHONE CARTRIDGE

Dimensions:

	Diameter	Height
With protecting grid	13.2 mm (0.52 in)	12.7 mm (0.5 in)
Without protecting grid	12.7 mm (0.5 in)	11.5 mm (0.45 in)
Coupler/Grid Mounting Thread	12.7 mm (0.5 in)	60 NS2
Preamplifier Mounting Thread	11.7 mm (0.46 in)	60 NS2

Polarization Voltage: 200 volts

Open Circuit Sensitivity: 12.5 mV per pascal* at 250 Hz
−38 dB re 1 mV per pascal (individually calibrated)

Frequency Response (free field):
0^{o} incidence
6 Hz to 10 kHz ± 1.0 dB
5 Hz to 20 kHz ± 1.5 dB
4 Hz to 40 kHz ±2.0 dB (individually calibrated)

−3 dB Point: 1 Hz to 3 Hz

Resonance Frequency:
(for 90^{o} Phase shift) approx. 25 kHz

Dynamic Range:
(open circuit)
Lower limit determined by preamplifier noise
Upper limit (4% distortion)
164 dB re 20 μ pascals

Capacitance (polarized): 18 pF (individually calibrated)

* 1 pascal = 1 N/m^2 = 10 μbar.

Equivalent Air Volume:	approx. 0.01 cm^3
Influence of Temperature:	From -50^oC to $+ 60^oC$ better than 0.006 $dB/^oC$
Influence of Ambient Pressure:	−0.1 dB/100 mmHg
Influence of Vibration:	1 g in axial direction is equivalent to a sound pressure level 88 dB re 20 μpascal
Influence of Humidity:	$<$0.1 dB in absence of condensation
Influence of Magnetic Field:	100 A/m equivalent to a sound pressure level of 20 dB re 20 μ pascals
Long term stability:	
at 25^oC (extrapolated)	of the order of 1 dB per 900 years
at 150^oC	of the order of 1 dB per 2 hours

5.2. TYPE 4134 PRESSURE (RANDOM INCIDENCE) RESPONSE MICROPHONE CARTRIDGE

Dimensions:

	Diameter	Height
Diameter		
With protecting grid	13.2 mm (0.52 in)	12.7 mm (0.5 in)
Without protecting grid	12.7 mm (0.5 in)	11.5 mm (0.45 in)
Coupler/Grid Mounting Thread	12.7 mm (0.5 in)	60 NS2
Preamplifier Mounting Thread	11.7 mm (0.46 in)	60 NS2

Polarization Voltage:	200 volts
Open Circuit Sensitivity:	12.5 mV per pascal at 250 Hz −38 dB re 1 mV per pascal (individually calibrated)
Frequency Response (pressure):	10 Hz to 5 kHz ± 0.5 dB 5 Hz to 10 kHz ± 1.5 dB 4 Hz to 20 kHz ± 2.0 dB (individually calibrated)
−3 dB Point	1 Hz to 3 Hz

Resonance Frequency: (for 90° phase shift)	approx. 25 kHz
Dynamic Range: (open circuit)	Lower limit determined by preamplifier noise Upper limit (4% distortion) 164 dB re 20 μ pascals
Capacitance (polarized):	18 pF (individually calibrated)
Equivalent Air Volume:	approx. 0.01 cm^3
Influence of Temperature:	From −50°C to + 60°C better than 0.006 dB/°C
Influence of Ambient Pressure:	−0.1 dB/100 mmHg
Influence of Vibration:	1 g in axial direction is equivalent to a sound pressure level of 88 dB re 20 μpascals
Influence of Humidity:	$<$0.1 dB in absence of condensation
Influence of Magnetic Field:	100 A/m equivalent to a sound pressure level of 20 dB re 20 μ pascals
Long term stability:	
at 25°C (extrapolated)	of the order of 1 dB per 900 years
at 150°C	of the order of 1 dB per 2 hours

5.3. TYPE 4147 LOW FREQUENCY MICROPHONE CARTRIDGE

Dimensions:

	Diameter:	Height:
With protecting grid	13.2 mm (0.52 in)	16.3 mm (0.64 in)
Without protecting grid	12.7 mm (0.50 in)	15.1 mm (0.59 in)
Coupler/Grid mounting thread	12.7 mm (0.50 in)	60 NS2
Preamplifier mounting thread	11.7 mm (0.46 in)	60 NS2

Open Circuit Sensitivity (28 volts polarization):	−56 dB re 1 volt per pascal at 250 Hz (1.58 mV per pascal)
Capacitive Sensitivity:	1.1×10^{-3} pF per pascal at 250 Hz

The following specifications apply equally to the microphone when used with 28 volts polarization and when fitted to the Microphone Carrier System Type 2631 via the Adaptor UA 0271:

Frequency Response (pressure response):	0.02 Hz to 5 kHz ± 0.5 dB 0.01 Hz to 16 kHz ± 1.0 dB 0.005 Hz to 20 kHz ± 3.0 dB (individually calibrated)
−3 dB Point	0.001 Hz to 0.005 Hz
Time Constant of Pressure Equalization:	32 to 160 sec. (individually calibrated)
Equivalent Air Volume:	approx. 0.01 cm^3
Influence of Temperature:	From −50°C to + 60°C better than −0.006 dB/°C
Influence of Ambient Pressure:	−0.03 dB/100 mmHg
Influence of Vibration:	1 g in axial direction is equivalent to a sound pressure level of 88 dB re 20 μpascals
Influence of Humidity:	< 0.1 dB in absence of condensation
Influence of Magnetic Field:	100 A/m is equivalent to a sound pressure level of 20 dB re 20 μ pascals
Long term stability:	
at 25°C (extrapolated)	of the order of 1 dB per 900 years
at 150°C	of the order of 1 dB per 2 hours

5.4. TYPE 4149 FREE FIELD RESPONSE OUTDOOR MICROPHONE CARTRIDGE

Dimensions

	Diameter	Height
With protecting grid	13.2 mm (0.52 in)	12.7 mm (0.5 in)
Without protecting grid	12.7 mm (0.5 in)	11.5 mm (0.45 in)
Coupler/Grid Mounting Thread	12.7 mm (0.5 in)	60 NS2
Preamplifier Mounting Thread	11.7 mm (0.46 in)	60 NS2

Polarization Voltage: 200 volts

Open Circuit Sensitivity: 12.5 mV per pascal at 50 Hz
−38 dB re 1 mV per pascal
(individually calibrated)

Frequency Response (free field): 6 Hz to 10 kHz ± 1.0 dB
0° Incidence 5 Hz to 20 kHz ± 1.5 dB
4 Hz to 40 kHz ± 2.0 dB
(individually calibrated)
−3 dB Point 1 Hz to 3 Hz

Resonance Frequency:
(for 90° Phase shift) approx. 24 kHz

Dynamic Range:
(open circuit) Lower limit determined by preamplifier noise
Upper limit (4% distortion)
164 dB re 20 μ pascals

Capacitance (polarized): 18 pF (individually calibrated)

Equivalent Air Volume: approx. 0.01 cm^3

Influence of Temperature: From −50°C to + 60°C
better than −0.006 dB/°C

Influence of Ambient Pressure: −0.1 dB/100 mmHg

Influence of Vibration:	1 g in axial direction is equivalent to a sound pressure level 88 dB re 20 μpascals
Influence of Humidity:	0.1 dB in absence of condensation
Influence of Magnetic Field:	100 A/m equivalent to a sound pressure level of 20 dB re 20 μ pascals
Long term stability:	
at 25°C (extrapolated)	better than 1 dB per 150 years
at 150°C	better than 1 dB per 0.33 hours

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Microphone Calibrators

ACOUSTICAL RESPONSE TESTING
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Random Noise Generators
Sine-Random Generators
Artificial Voices
Artificial Ears
Artificial Mastoids
Hearing Aid Test Boxes
Audiometer Calibrators
Telephone Measuring Equipment
Audio Reproduction Test Equipment
Tapping Machines
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VIBRATION MEASUREMENTS
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Force Transducers
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Vibration Meters
Accelerometer Calibrators
Magnetic Transducers
Capacitive Transducers
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Automatic Selectors

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